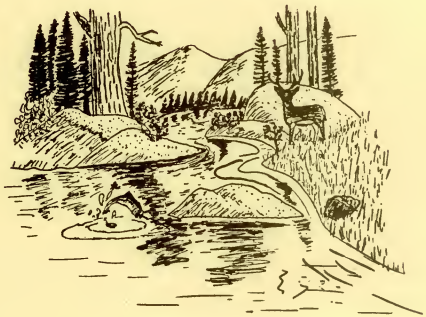
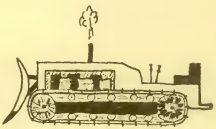
LOGAN CREEK WATER QUALITY STUDY





WATER QUALITY BUREAU

Environmental Sciences Division

Montana Department of Health and Environmental Sciences

1976

Technical Report

LOGAN CREEK WATER QUALITY STUDY
FISCAL YEAR 1976 REPORT

Submitted To:

U.S.D.A. Forest Service
Forest Supervisor
Flathead National Forest
Kalispell, Montana
59901

Prepared By:

Geoffrey Hughes
Montana Department of Health
and Environmental Sciences
Kalispell Regional Office

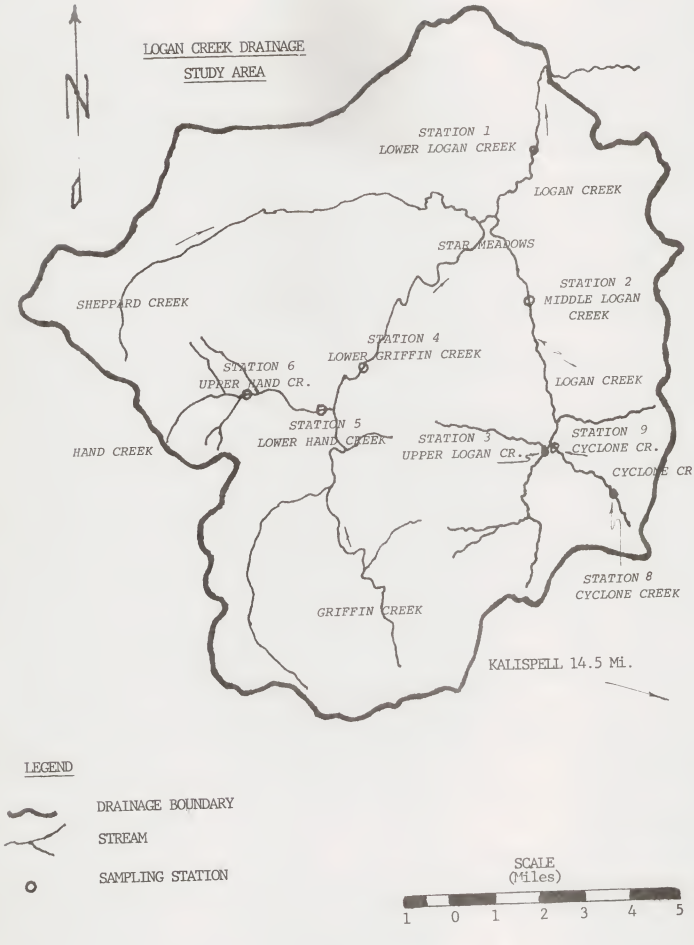
January, 1977

INTRODUCTION

The attached report was prepared by the Montana Department of Health and Environmental Sciences under contract to the Flathead National Forest during fiscal year 1976 and the transition quarter, 1976. It represents a continuation of the study which was undertaken in 1975 and which is published in technical report 75-2 prepared by the Montana Water Quality Bureau.

Sample collection and field analyses were accomplished by the Kalispell Regional Office of the Montana Department of Health and Environmental Sciences, principally in the person of Mr. Geoffrey Hughes, Water Quality Specialist, with assistance by other members of the regional office staff. Many of the chemical analyses were carried out by the Department's chemistry laboratory in Helena.

The study area is located on the Tally Lake Ranger District of the Flathead National Forest. The drainage is the same as that which was described in technical report 75-2. Several of the parameters were changed so that the data would correspond to data which is being collected at other locations in the Northwest Region. Sampling at the Dunsire Creek location was discontinued at the end of fiscal year 1975 in favor of a more suitable location. Such a sampling site was located on Cyclone Creek and sampling was initiated on Cyclone Creek in September, 1975.


LOGAN CREEK DRAINAGE
STUDY AREA
N
STATION 1
LOWER LOGAN CREEK
LOGAN CREEK
STAR MEADOWS
STATION 2
MIDDLE LOGAN
CREEK
SHEPPARD CREEK
STATION 4
LOWER GRIFFIN CREEK
STATION 6
UPPER HAND CR.
LOGAN CREEK
STATION 5
LOWER HAND CREEK
STATION 3
UPPER LOGAN CR.
STATION 9
CYCLONE CR.
HAND CREEK
CYCLONE CR.
STATION 8
CYCLONE CREEK
GRIFFIN CREEK
KALISPELL 14.5 Mi.
LEGEND
DRAINAGE BOUNDARY
STREAM
SAMPLING STATION
SCALE
(Miles)
1 0 1 2 3 4 5

THE SAMPLING NETWORK

Sampling Stations 1 through 6 were the same throughout the test period as those described in the fiscal year 1975 report. In addition, Station #8 was added on Cyclone Creek and is described as follows:

Station 8, Cyclone Creek SE¼ SW¼ NE¼ Section 14, Township 29 North, Range 24 West.

Station 9, Cyclone Creek SW¼ SE¼ SW¼ Section 10, Township 29 North, Range 24 West.

These new sampling stations are further described below:

Station 8, Cyclone Creek

This station is located upstream from any current activity and also any planned activity. It is reached by a hiking trail some 2 miles above the end of the Logan Creek road. On September 3, 1975, a thermograph and staff gauge were installed at this location. The samples on September 3 and September 22, 1975 were both taken at this location.

Station 9, Cyclone Creek

This station is located along the Meadow Creek trail at the point at which it crosses Cyclone Creek. The station is upstream from any current forestry activities, but is downstream from the proposed road crossing on Cyclone Creek. Sampling at this location prior to, during and after road construction, should provide interesting data regarding effects of road building on Cyclone Creek.

Comments on Cyclone Creek Locations

The area between Logan Creek and Cyclone Creek is a virgin forest in which extensive timber harvesting has been planned. The upper location on Cyclone Creek was selected as a control station since it is upstream from any proposed road building or timber harvest.

During the winter of 1975-76 it was decided that the opportunity should be taken to sample below the road crossing on Cyclone Creek. For this reason, the samples from this point on were collected at the station described as Station 9. Station 8, Upper Cyclone Creek is intended for use in the future as a control station and for this reason the thermograph and staff gauge were left at this location.

Comments on Parameter Selection and Data Collection

Parameter selection was altered so that each sample would be analyzed for the following parameters: air and water temperature, stream flow, alkalinity, total suspended sediment, turbidity, pH, fecal coliforms, specific conductance, organic color, nitrate + nitrite, ortho-phosphate, sodium, potassium, chloride, sulfate, calcium and magnesium.

The acquisition of additional equipment permitted the measurement of bedload by means of a Helly-Smith bedload sampler. A DH 48 suspended sediment sampler was used to gather all samples to be analyzed.

As a result of the addition of these new parameters, the cost of analysis was raised and to stay within the budget limitations of the project, it was necessary to reduce the sampling frequency to 12 times per year. The sampling frequency was greatest in the spring and the sample collector was permitted a certain amount of flexibility so that samples could be collected immediately following a hydrologic event.

Considerable difficulty was experienced in maintaining the recording thermographs in an operating condition. Examination of the data from these instruments reflects the rather large gaps that were the result of the difficulties in maintenance. At the present, all of the thermographs have been removed from the study area and will be serviced during the winter and reinstalled in the spring of 1977.

PART I

PHYSICAL AND CHEMICAL ASSESSMENT

Hand Creek Stations 5 & 6

As indicated in the 1975 report Stations 5 and 6 on Hand Creek provided suitable locations above and below considerable logging and road building activity. Since the completion of that report logging activity has been increased to compare current data to the previous data to look for the effect of this increased activity.

Fecal coliform concentrations indicate that both stations are still of excellent bacteriological quality. Organisms of this group were detected on only 4 occasions. Turbidity measurements, in almost every instance, were somewhat higher at Station 5 than at Station 6 and were generally lower than those recorded during the previous reporting period. Suspended sediment measurements showed the same general trend as turbidity, with little change between the two monitoring locations; with two notable exceptions. On May 6, 1976 this parameter reflected a five fold increase between these stations. On May 13, 1976 a 6 fold increase was noted.

Organic color is the parameter which showed the most profound change on Hand Creek. Data from the 1975 report reflect maximum values at Station 6 in the order of 30 Pt-Co units. 1976 values were sometimes as high as 50 units and were consistently over 20 during the peak flow periods. On 5 occasions, organic color at Station 6 exceeded that at Station 5. This represents a noticeable change from the previous year.

Specific conductance showed virtually no change from the previous year's data. Values were in the range which one would expect based on the geology of the drainage. No significant trends were noticed in bedload, nutrients, pH or the chemical constituents monitored.

Griffin Creek Station 4

Examination of the data shows little change in water quality at this station between 1975 and 1976. Organic color was still rather high, peaking at 55 units. Turbidity and suspended solids were somewhat reduced from the previous reporting year. This station showed evidence of bacterial contamination more frequently than any of those studied except Lower Logan Creek. This is the result of extensive use of the upper reaches of the drainage by livestock.

Because of the lack of a suitable control location, the value of the Griffin Creek station to this study is questionable. Since data is now published for over 2 years samples at this location, it would serve to reflect the impact of any further upstream activity. However, in view of the limitation imposed on the number of stations to be studied, another location in the study area, where satisfactory controls can be utilized might prove to be more valuable.

Logan Creek Station 1

By virtue of its downstream location, this station reflects the water quality of the entire drainage. As one would expect, the poorest conditions of the entire sampling network were found here.

The presence of fecal coliform bacteria was detected in 70% of the samples collected, reaching a peak of 42 colonies/100 ml. Values for turbidity and suspended solids were higher than the rest of the drainage with the exception of a few values recorded at Station 4. Similarly, organic color values were generally higher than all other locations except Station 4 and an occasional value at Station 6. The warming effect of Star Meadows was noticeable in the temperature data, which reached a high of 68°F. Levels of nutrients and dissolved minerals were not significant.

Station 1, located on Logan Creek just upstream from fourth bridge, was selected because it is downstream from the entire study area. Effects of activity anywhere in the basin could be monitored at this location. Unfortunately, it is also downstream from Star Meadows; a large, marshy area of slow moving water. The effects of Star Meadows on water quality masks the effects of timber harvest practices.

The Meadow provides a large, natural settling basin which probably decreases the suspended sediment measured at Station 1. In addition, this large open area permits increases in temperature, which are unrelated to forest management. Third, and perhaps most important, it houses the Star Meadows Ranch. Any changes in water quality noticed at this location could just as readily be attributed to ranch activities as to forestry activities. Perhaps this station, too, could be relocated where it would provide data more suited to the intentions of the study.

Middle and Upper Logan Creek Stations 2 & 3

The bacteriological conditions at both these stations was good throughout the study. The highest recorded concentrations of fecal coliforms was 7 organisms/ 100 ml at Station 3. The changes in total suspended sediment and organic color between these two stations is in order of what one would expect from natural conditions.

It is interesting to notice the turbidity data at Stations 2 and 3, especially as it compares with the data at Stations 5 and 6. There is a general increase in turbidity between Stations 2 and 3. During spring runoff one might attribute this to the activity which has taken place in this part of the drainage. However, the changes are much less profound than those recorded on Hand Creek. As suggested in the 1975 report, this might be the result of the relative age of the timber sales in these two drainages. Presumably the effects on Hand Creek would become less noticeable with the passage of time. Continued sampling at these stations will serve to test this hypothesis.

In this portion of the drainage the concentration of nutrients and dissolved minerals was as would be expected.

Cyclone Creek Station 8

Cyclone Creek is of excellent bacteriological quality. Analyses for fecal coliforms were positive on only 2 occasions. Data for turbidity and suspended sediment seem somewhat high on occasion, considering the pristine location of this stream. The lacustrine soils and silt loams in the drainage are probably contributing to these high values. However, it should be borne in mind that, because of low flow, the DH-48 sampler was not used to sample this stream. Grab samples rather than depth integrated samples were used, and it was difficult for the sampler to fill the sample bottle in this shallow stream without disturbing the stream bottom at the sampling location.

Organic color reached a maximum of 12 units, which is about what could be expected naturally. The high values of pH and alkalinity, as well as specific conductance are characteristic of the geology of the drainage.

Nothing remarkable was noted in the nutrients or chemical constituents analyzed. Bedload reached a maximum of 3.5 oz. in a ten minute sample.

Conclusions Based on Data

Based on the preceeding discussion and the data presented in Appendix I, certain conclusions can be drawn:

(1) Areas where considerable logging is taking place close to streams reflect an increase in suspended sediment loading. This is best seen in the difference between the data from Stations 5 and 6.

(2) These effects are mitigated by greenbelts of untouched timber between the logging operation and the stream. The relatively minor changes in the data at Station 6 reflect this.

(3) As suggested in the 1975 report, water quality improves to essentially natural conditions after 3 or 4 years following the activity.

State Water Quality Standards

The entire Logan Creek drainage has been classified as B-D1 in the state water quality standards. This essentially sets the following limitations on water quality:

Fecal coliform counts must average less than 200 organisms per 100 ml.

Dissolved oxygen must not be reduced below 7.0 ppm.

Induced pH variation, within the range 6.5 to 8.5 is to be less than 0.5 pH unit.

Maximum allowable increase above naturally occurring turbidity is 5 Jackson Candle Units.

Maximum allowable temperature increase, within the range of 32°F to 66°F, is 1°F.

No increase allowed above naturally occurring concentrations of sediment, settleable solids, or residues.

True color limit above naturally occurring levels is 5 units.

As suggested in the previous report, it is difficult to determine what constitutes naturally occurring changes in sediment, turbidity and organic color. Therefore, it is difficult to determine if a change in these parameters constitutes a violation of water quality standards. Nevertheless, it seems likely that the change in suspended sediment from 7 mg/l to 36 mg/l which occurred between Stations 5 and 6 on May 6, 1976 is at least in part due to logging operations in the drainage; and as such is in violation.

Suggestions for Continued Monitoring

It is recommended that the monitoring program be continued in an effort to further test the conclusions made in this report and the 1975 report. Because of the planned activity in the Cyclone Creek area, surveillance should be concentrated in this area. The relocation of Station 1 or Station 4 or both to the Cyclone-Upper Logan Creek area should be considered.

Water Quality

In general, the water quality in the entire drainage under consideration was found to be excellent. The stations located downstream from recently logged areas, Station 2 and Station 5, showed noticeable improvement in water quality since 1975. As expected, water quality is porest during spring runoff, but the changes noted were minimal.

APPENDIX I

PHYSICAL AND CHEMICAL DATA

FIELD TEMPERATURE (°F)

#1 Lower Logan Creek	#2 Middle Logan Creek	#3 Upper Logan Creek	#4 Griffin Creek	#5 Lower Hand Creek	#6 Upper Hand Creek	#8 Creek	
65	59	57	58	58	57		7/16/75
68	58	56	56	55	55		7/30/75
53	55	60	51	50	47		8/12/75
43	46	45	50	50	49		8/27/75
43	47	40	49	43	45	42	9/3/75
47	48	48	47	43	46	42	9/22/75
32							4/7/76
42	37	38	38	36	36	37	5/6/76
46	38	39	42	40	39	38	5/13/76
44	40	38	44	42	38	38	5/21/76
46	43	42	43	41	39	40	6/3/76
45	45	44	50	47	43	44	6/17/76
62	56	52	54	50	49	58	7/3/76
60	56	55	57	53	50	52	7/9/76
63	60	58	59	55	50	53	7/27/76
62	55	57	55	55	50	50	8/3/76
58	47	46	45	48	46	48	8/31/76
53	44	40	42	42	42		9/28/76

FECAL COLIFORMS #/100 ml

	#1 Lower Logan Creek	#2 Middle Logan Creek	#3 Upper Logan Creek	#4 Griffin Creek	#5 Lower Hand Creek	#6 Upper Hand Creek	#8 Cyclone Creek
7/16/75	12	3	3	8	0	0	
7/30/75	9	1	7	11	1	1	
8/12/75	10	3	0	11	1	0	
8/27/75	3	2	0	3	0	0	
9/3/75	0	0	0	0	0	0	0
9/22/75	0	0	0	3	0	0	0
4/7/76	42						
5/6/76	3	1	0	2	1	0	0
5/13/76	4	0	1	0	0	0	1
5/21/76	2	0	2	0	0	0	0
6/3/76	5	0	1	2	0	0	0
6/17/76	4	0	0	6	0	0	0
7/3/76	2	0	0	0	0	0	0
7/9/76	14	3	2	2	4	6	1
7/27/76	0	0	0	0	0	0	0
8/3/76	0	0	0	0	0	0	0
8/31/76	0	0	0	1	0	0	0
9/28/76	0	0	0	0	0	0	

BED LOAD (OZ.)

#1 Lower Logan Creek	#2 Middle Logan Creek	#3 Upper Logan Creek	#4 Griffin Creek	#5 Lower Hand Creek	#6 Upper Hand Creek	#8 Cyclone Creek	
							7/16/75
							7/30/75
							8/12/75
							8/27/75
							9/3/75
							9/22/75
							4/7/76
TR	2.7	0.3	8.5	4	0.3	TR	5/6/76
	28	0.5	27.5	6.25	7.5	1.0	5/13/76
0	7.5	0.5	3.5	0	0.5	TR	5/21/76
2.5	8.5	1.0	4.5	1.5	1.5	1.5	6/3/76
3.5	0.5	2.5	3.5	TR	TR	3.5	6/17/76
3.0	0.5	2.0	2.5	0	0	1.0	7/3/76
3.0	0.5	1.5	2.5	0	0	0.5	7/9/76
2.8	0	1.5	2.0	0	0	0	7/27/76
3.0	0	1.0	0	0	0	0	8/3/76
2.0	0	0	TR	0	0	0	8/31/76
0	0	0	0	0	0		9/28/76

TURBIDITY (JTU)

#8 Cyclone Creek	#6 Upper Hand Creek	#5 Lower Hand Creek	#4 Griffin Creek	#3 Upper Logan Creek	#2 Middle Logan Creek	#1 Lower Logan Creek	
-	0.3	0.2	0.3	0.3	0.5	1.0	7/16/75
-	0.2	0	0.7	0.6	0.3	0.3	7/30/75
	0.4	0.3	0.3	0.4	0.4	0.5	8/12/75
	0.4	0.4	0.3	0.3	0.5	0.4	8/27/75
0.2	0.2	0.4	0.6	0.6	0.2	0.3	9/3/75
0.3	0.7	0.6	0.6	0.4	0.4	0.7	9/22/75
						3.1	4/7/76
2.5	1.6	6.0	5.5	1.0	2.5	3.2	5/6/76
0.5	0.7	4.5	6.0	1.8	3.1	3.5	5/13/76
0.6	0.4	0.9	1.0	0.6	0.9	0.9	5/21/76
0.2	0.3	0.6	0.8	0.3	0.5	0.7	6/3/76
0.3	0.3	0.7	2.0	0.3	0.6	0.9	6/17/76
0.8	0.7	0.8	0.9	0.8	0.7	1.0	7/3/76
0.6	0.6	0.7	1.6	0.5	0.9	0.9	7/9/76
0.5	0.1	0	0.2	0.1	0.4	0.6	7/27/76
0.5	0.4	0.5	0.8	0.3	0.1	0.4	8/3/76
0.3	0.4	0.3	0.1	0.4	0.1	0.4	8/31/76
	0.3	0.1	0.4	0.3	0.4	0.1	9/28/76

TOTAL SUSPENDED SEDIMENT (MG/L)

	#1 Lower Logan Creek	#2 Middle Logan Creek	#3 Upper Logan Creek	#4 Griffin Creek	#5 Lower Hand Creek	#6 Upper Hand Creek	#8 Lychaue Creek
7/16/75	5.0	0	0	6	0	0	
7/30/75	0	0	5	20	0	0	
8/12/75	5	3	2	5	3	5	
8/27/75	4	3	3	5	5	9	
9/3/75	0	0	0	0	0	0	0
9/22/75	0	0	0	0	3	0	3
4/7/76	5						
5/6/76	10	19	10	26	36	7	20
5/13/76	2.0	0	0	17	6	0	8
5/21/76	2.0	0	0	0	0	0	0
6/3/76	16.0	10	8	6	8	9	22
6/17/76	3.0	0	2	9	1	0	0
7/3/76	0	0	0	0	0	0	0
7/9/76	1.0	0	0	0	0	0	1
7/27/76	0	0	0	0	0	0	0
8/3/76	0	0	0	0	0	0	0
8/31/76	0	0	0	0	0	0	0
9/28/76	0	0	0	0	0	0	

ORGANIC COLOR (Pt/Co Units)

	#1 Lower Logan Creek	#2 Middle Logan Creek	#3 Upper Logan Creek	#4 Griffin Creek	#5 Lower Hand Creek	#6 Upper Hand Creek	#8 Cyclone Creek
7/16/75	7	0	0	10	2	0	-
7/30/75	10	4	5	7	0	0	-
8/12/75	10	1	3	1	0	0	
8/27/75	7	0	5	0	3	0	
9/3/75	4	0	0	0	0	0	2
9/22/75	7	0	0	0	0	0	0
4/7/76	21						
5/6/76	15	5	3	17	6	12	0
5/13/76	30	9	10	33	30	34	10
5/21/76	34	21	15	40	25	32	12
6/3/76	25	10	15	40	17	25	8
6/17/76	10	15	15	55	55	50	10
7/3/76	20	13	13	20	16	20	10
7/9/76	10	13	10	20	20	15	5
7/27/76	3	0	0	0	0	0	5
8/3/76	3	0	0	0	0	0	0
8/31/76	3	0	0	2	0	0	0
9/28/76	0	0	0	0	0	0	

SODIUM (mg/L)

#1 Lower Logan Creek	#2 Middle Logan Creek	#3 Upper Logan Creek	#4 Griffin Creek	#5 Lower Hand Creek	#6 Upper Hand Creek	#8 Cyclone Creek	
							7/16/75
							7/30/75
							8/12/75
							8/27/75
							9/3/75
							9/22/75
							4/7/76
1.5	1.4	1.1	1.4	1.3	1.2	1.3	5/6/76
0.9	0.6	0.9	0.9	0.9	0.7	0.9	5/13/76
2.2	2.1	2.0	2.0	2.2	2.1	2.1	5/21/76
2.2	2.5	1.9	2.2	2.2	2.1	2.2	6/3/76
1.8	1.5	1.4	2.0	2.0	1.8	1.3	6/17/76
2.0	1.9			2.3	1.9	1.8	7/3/76
1.8	1.5	1.3	2.0	2.0	1.8	1.2	7/9/76
2.3	2.0	1.4	2.8	2.4	2.5	1.7	7/27/76
2.2	1.9	1.4	2.7	3.0	2.4	1.7	8/3/76
2.3	2.0	1.5	2.9	3.0	2.6	1.7	8/31/76
2.4	2.1	1.5	3.0	3.2	2.7		9/28/76

POTASSIUM (mg/l)

	#1 Lower Logan Creek	#2 Middle Logan Creek	#3 Upper Logan Creek	#4 Griffin Creek	#5 Lower Hand Creek	#6 Upper Hand Creek	#8 Cyclone Creek
7/16/75							-
7/30/75							-
8/12/75							
8/27/75							
9/3/75							
9/22/75							
4/7/76							
5/6/76	0.9	1.0	0.9	0.7	0.7	0.8	1.5
5/13/76	0.8	1.0	0.8	0.6	0.6	0.6	1.5
5/21/76	0.80	0.80	0.80	0.60	0.60	0.60	1.2
6/3/76	0.80	0.90	0.80	0.80	0.80	0.70	1.2
6/17/76	1.31	1.57	1.54	1.0	1.09	1.06	1.91
7/3/76	1.26	1.69			1.19	1.04	2.05
7/9/76	1.06	1.26	1.31	1.19	1.13	0.97	1.91
7/27/76	1.30	1.9	1.6	1.4	1.4	1.3	2.4
8/3/76	0.8	1.0	0.9	0.9	0.8	0.43	0.93
8/31/76	0.9	1.1	1.0	0.9	1.1	0.9	1.4
9/28/76	0.8	1.0	0.8	0.8	0.8	0.6	

MAGNESIUM (mg/l)

#8 Deluge Creek	#6 Upper Hand Creek	#5 Lower Hand Creek	#4 Griffin Creek	#3 Upper Logan Creek	#2 Middle Logan Creek	#1 Lower Logan Creek	
							7/16/75
							7/30/75
							8/12/75
							8/27/75
							9/3/75
							9/22/75
							4/7/76
							5/6/76
6.0	0.5	1.4	1.6	2.7	6.4	2.8	5/13/76
10.2	1.5	3.3	0.8	19.4	3.1	5.1	5/21/76
8.5	1.2	1.0	0.7	0.7	10.7	6.7	6/3/76
13.5	1.1	4.8	1.6	36.0	9.6	6.4	6/17/76
14.5	1.2	1.5			13.6	9.6	7/3/76
5.9	0.5	1.2	4.6	6.8	17.8	9.4	7/9/76
17.1	1.8	1.6	8.2	8.3	11.9	10.6	7/27/76
12.4	1.3	0.9	4.2	7.7	14.0	8.7	8/3/76
11.6	0.5	1.0	4.5	7.2	10.7	9.3	8/31/76
	0.2	1.1	7.8	7.4	13.2	11.6	9/28/76

CHLORIDE (mg/l)

	#1 Lower Logan Creek	#2 Middle Logan Creek	#3 Upper Logan Creek	#4 Griffin Creek	#5 Lower Hand Creek	#6 Upper Hand Creek	#8 Cyclone Creek
7/16/75							
7/30/75							
8/12/75							
8/27/75							
9/3/75							
9/22/75							
4/7/76							
5/6/76	0.5	0.6	0.4	0.8	0.5	0.6	1.5
5/13/76	0.5	0.4	0.5	0.5	0.4	0.3	0.4
5/21/76	0.9	0.4	1.8	1.5	2.6	0.7	6.7
6/3/76	1.2	2.9	0.3	0.8	0.4	0.9	1.1
6/17/76	0.8	1.9	0.9	0.8	1.5	0.8	0.9
7/3/76	0.9	1.7			0.8	0.8	0.8
7/9/76	0.8	0.8	2.0	0.8	0.9	0.8	0.9
7/27/76	1.0	0.9	0.8	0.8	1.0	0.3	0.8
8/3/76	0.7	0.6	0.6	4.7	2.7	0.3	0.4
8/31/76	0.6	0.6	0.4	0.6	0.5	1.0	1.2
9/28/76	0.9	0.9	1.3	1.0	0.9	0.9	

SULFATE (mg/l)

#8 Cr. Lone Creek	#6 Upper Hand Creek	#5 Lower Hand Creek	#4 Griffin Creek	#3 Upper Logan Creek	#2 Middle Logan Creek	#1 Lower Logan Creek	
							7/16/75
							7/30/75
							8/12/75
							8/27/75
							9/3/75
							9/22/75
							4/7/76
1.3	1.3	1.3	1.2	1.0	1.2		5/6/76
1.5	1.5	1.5	1.3	1.1	1.1	1.5	5/13/76
1.4	1.2	1.2	1.0	1.2	1.4	1.2	5/21/76
2.6	1.2	1.2	1.2	2.4	2.9	1.2	6/3/76
1.0	2.0	2.0	2.0	2.0	2.5	2.5	6/17/76
1.0	1.0	1.5			2.5	2.0	7/3/76
2.5	1.0	2.0	2.5	2.6	2.5	2.6	7/9/76
2.5	1.3	1.0	2.5	1.0	2.5	1.3	7/27/76
2.5	0.0	1.0	3.0	1.0	1.0	1.0	8/3/76
1.0	1.0	1.0	1.0	1.0	3.0	2.0	8/31/76
	0.4	0.7	0.5	0.7	0.7	0.0	9/28/76

TOTAL ALKALINITY (As $CaCO_3$)

	#1 Lower Logan Creek	#2 Middle Logan Creek	#3 Upper Logan Creek	#4 Griffin Creek	#5 Lower Hand Creek	#6 Upper Hand Creek	#8 Cyclone Creek
7/16/75							
7/30/75							
8/12/75							
8/27/75							
9/3/75							
9/22/75							
4/7/76							
5/6/76	39	63	54	14.1	9.5	5.2	91
5/13/76	52	98	85	17	9	4	160
5/21/76	56	120	96	10	26	15	173
6/3/76	88	141	111	40	15	8	187
6/17/76	105	151	123	28	28	8	178
7/3/76	118	172	131		21	12	191
7/9/76	122	165	132	64	24	12	185
7/27/76	139	172	141	80	21	15	201
8/3/76	142	180	139	74	25	12	185
8/31/76	127	189	153	78	22	13	198
9/28/76	154	194	152	92	32	18	

CALCIUM (mg/l)

#1 Lower Logan Creek	#2 Middle Logan Creek	#3 Upper Logan Creek	#4 Griffin Creek	#5 Lower Hand Creek	#6 Upper Hand Creek	#8 Cyclone Creek	
							7/16/75
							7/30/75
							8/12/75
							8/27/75
							9/3/75
							9/22/75
							4/7/76
13.2	24.8	21.3	4.1	1.8	1.7	43	5/6/76
14.7	30.6	28.8	5.0	3.0	2.2	54	5/13/76
18.8	42.9	6.4	1.6	6.6	4.4	54	5/21/76
23.7	41.7	44.1	14.4	3.8	1.1	60	6/3/76
28.2	45.0	36.0	7.3	3.8	1.8	48.3	6/17/76
31.4	48.9			4.4	2.1	51	7/3/76
33.4	37.0	42.1	17.6	6.7	2.8	61	7/9/76
38.6	50	42.4	18.5	5.5	2.6	53	7/27/76
40.1	45.9	41.8	22.4	8.2	1.4	54	8/3/76
35.1	55.0	45.0	21.5	6.8	3.2	57	8/31/76
42.2	55.0	46.7	23.2	7.9	6.1		9/28/76

DISSOLVED OXYGEN

#8 Cyclone Creek	#6 Upper Hand Creek	#5 Lower Hand Creek	#4 Griffin Creek	#3 Upper Logan Creek	#2 Middle Logan Creek	#1 Lower Logan Creek	
	9.87	9.11	9.06	10.05	8.70	8.05	7/16/75
	9.61	8.36	8.62	9.37	8.65	6.11	7/30/75
	8.96	9.12	9.51	9.61	9.73	8.02	8/12/75
	8.85	9.05	9.46	9.50	9.83	8.21	8/27/75
10.01	9.94	10.21	9.87	10.08	9.81	8.20	9/3/75
10.32	9.83	10.40	10.49	10.52	10.67	8.20	9/22/75
							4/7/76
							5/6/76
							5/13/76
							5/21/76
							6/3/76
							6/17/76
							7/3/76
							7/9/76
							7/27/76
							8/3/76
							8/31/76
							9/28/76

AIR TEMPERATURE (°F)

#8 Cyclone Creek	#6 Upper Hand Creek	#5 Lower Hand Creek	#4 Griffin Creek	#3 Upper Logan Creek	#2 Middle Logan Creek	#1 Lower Logan Creek	
	53	59	67	60	66	68	7/16/75
	61	66	74	63	70	71	7/30/75
	60	59	65	63	57	59	8/12/75
	59	62	68	58	57	69	8/27/75
51	54	60	62	53	51	61	9/3/75
48	50	57	60	45	45	48	9/22/75
							4/7/76
54	54	50	54	53	52	64	5/6/76
59	66	78	70	58	57	72	5/13/76
40	46	58	64	38	56	64	5/21/76
40	39	43	44	40	41	48	6/3/76
52	54	54	58	56	54	51	6/17/76
66	70	72	72	72	70	74	7/3/76
70	70	72	72	71	69	73	7/9/76
68	70	71	70	68	66	74	7/27/76
65	64	73		69	70	80	8/3/76
58	64	62	66	58	59	67	8/31/76
	64	65	65	61	66	68	9/28/76

GAUGE HEIGHT (FT.)

#8 Cyclone Creek	#6 Upper Hand Creek	#5 Lower Hand Creek	#4 Griffin Creek	#3 Upper Logan Creek	#2 Middle Logan Creek	#1 Lower Logan Creek	
		1.15		0.60	1.04	0.96	7/16/75
		1.12		0.48	1.00	0.76	7/30/75
		1.10		0.46	1.00	0.64	8/12/75
		1.02		0.41	0.98	0.63	8/27/75
		0.96		0.40	0.99	0.60	9/3/75
1.40		0.92		0.38	0.98	0.54	9/22/75
							4/7/76
		2.60	1.80	1.00	1.61	3.00	5/6/76
		2.60	1.69	1.48	2.00	3.60	5/13/76
		2.30	1.20	1.10	1.60	2.50	5/21/76
		1.80	0.65	0.85	1.32	1.75	6/3/76
		1.72	0.86	0.75	1.30	1.72	6/17/76
		1.38	0.70	0.57	1.06	1.00	7/3/76
		1.38		0.56	1.58	1.00	7/9/76
		1.18		0.46	1.00	0.90	7/27/76
	0.97	1.13	0.15	0.47	1.00	0.80	8/3/76
	0.97	1.10	0.10	0.40	0.90	0.68	8/31/76
	0.91	0.98	0.08	0.36	0.87	0.60	9/28/76

SPECIFIC CONDUCTANCE (μmhos/cm)

#8 Lyle Creek	#6 Upper Hand Creek	#5 Lower Hand Creek	#4 Griffin Creek	#3 Upper Logan Creek	#2 Middle Logan Creek	#1 Lower Logan Creek	
	45	45	170	280	285	265	7/16/75
	31	56	195	265	325	280	7/30/75
	39	65	170	275	335	275	8/12/75
	36	65	180	270	345	280	8/27/75
320	42	70	180	285	340	280	9/3/75
330	38	75	200	280	340	280	9/22/75
						185	4/7/76
290	29	51	66	195	220	120	5/6/76
265	21	32	50	170	190	92	5/13/76
160	42	34	57	200	230	150	5/21/76
295	26	41	86	225	265	180	6/3/76
310	28	54	73	240	275	220	6/17/76
360	28	50	69	265	310	235	7/3/76
345	29	52	140	255	305	250	7/9/76
360	30	55	150	260	300	250	7/27/76
355	29	48	145	245	300	250	8/3/76
370	30	50	150	245	295	250	8/31/76
	39	70	185	285	330	275	9/28/76

NITRATE + NITRITE (mg/l as N)

#1 Lower Logan Creek	#2 Middle Logan Creek	#3 Upper Logan Creek	#4 Griffin Creek	#5 Lower Hand Creek	#6 Upper Hand Creek	#8 Cyclone Creek	
0.03	0.03	0.03	0.03	0.03	0.03	.	7/16/75
0.03	0.03	0.03	0.03	0.03	0.03	.	7/30/75
0.03	0.03	0.03	0.03	0.03	0.03		8/12/75
0.03	0.03	0.03	0.03	0.03	0.03		8/27/75
0.03	0.03	0.03	0.03	0.03	0.03	0.03	9/3/75
0.03	0.03	0.03	0.03	0.03	0.03	0.03	9/22/75
0.04							4/7/76
0.02	0.04	0.04	0.02	0.08	0.02	0.06	5/6/76
0.02	0.04	0.04	0.04	0.03	0.02	0.07	5/13/76
0.06	0.01	0.01	0.01	0.01	0.01	0.01	5/21/76
0.01	0.19	0.01	0.01	0.01	0.01	0.01	6/3/76
0.01	0.01	0.03	0.01	0.01	0.01	0.05	6/17/76
0.02	0.20	0.01	0.03	0.01	0.03	0.01	7/3/76
0.01	0.01	0.02	0.01	0.01	0.13	0.01	7/9/76
0.01	0.02	0.01	0.01	0.01	0.01	0.04	7/27/76
0.01	0.01	0.01	0.01	0.01	0.01	0.04	8/3/76
0.01	0.02	0.01	0.01	0.01	0.01	0.01	8/31/76
0.01	0.01	0.31	0.01	0.05	0.01		9/28/76

O-PHOSPHATE

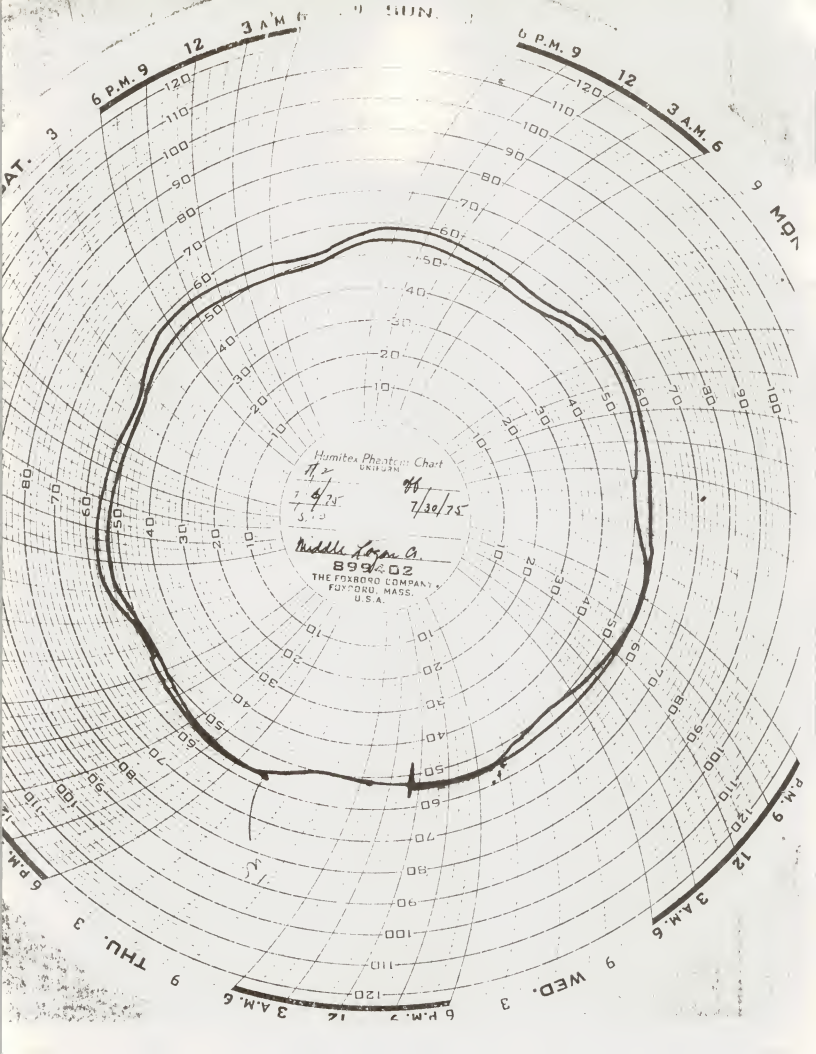
#8 Cyclone Creek	#6 Upper Hand Creek	#5 Lower Hand Creek	#4 Griffin Creek	#3 Upper Logan Creek	#2 Middle Logan Creek	#1 Lower Logan Creek	
	0.03	0.03	0.03	0.03	0.03	0.03	7/16/75
	0.03	0.03	0.03	0.03	0.03	0.03	7/30/75
	0.03	0.03	0.03	0.03	0.03	0.03	8/12/75
	0.03	0.03	0.03	0.03	0.03	0.03	8/27/75
0.03	0.03	0.03	0.03	0.03	0.03	0.03	9/3/75
0.03	0.03	0.03	0.03	0.03	0.03	0.03	9/22/75
						0.02	4/7/76
0.001	0.002	0.005	0.003	0.001	0.001	0.004	5/6/76
0.010	0.034	0.002	0.001	0.002	0.004	0.006	5/13/76
0.001	0.001	0.001	0.005	0.001	0.004	0.006	5/21/76
0.001	0.001	0.001	0.001	0.001	0.011	0.002	6/3/76
0.004	0.003	0.002	0.003	0.002	0.004	0.007	6/17/76
0.001	0.001	0.001	0.003	0.001	0.001	0.003	7/3/76
0.001	0.001	0.003	0.001	0.001	0.001	0.003	7/9/76
0.001	0.003	0.003	0.001	0.001	0.001	0.003	7/27/76
0.005	0.004	0.015	0.002	0.001	0.001	0.004	8/3/76
0.001	0.001	0.001	0.001	0.001	0.001	0.001	8/31/76
	0.004	0.004	0.004	0.004	0.003	0.003	9/28/76

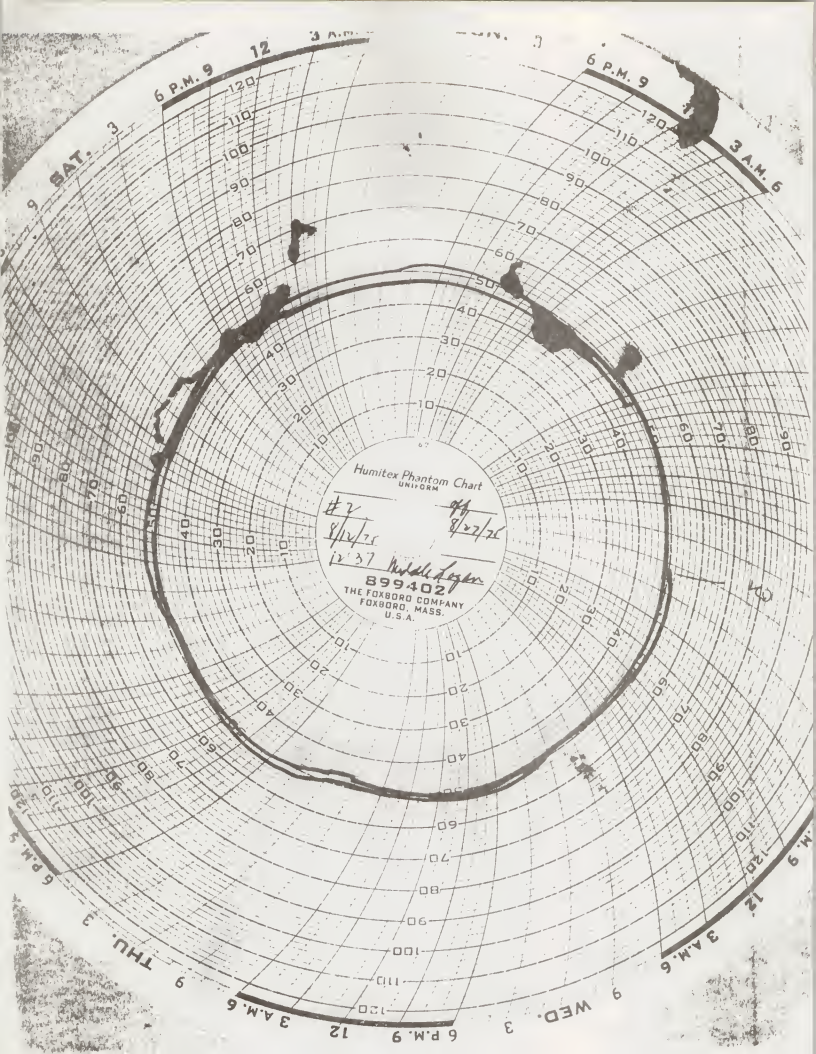
#8 Cyclone Creek	#6 Upper Hand Creek	#5 Lower Hand Creek	#4 Griffin Creek	#3 Upper Logan Creek	#2 Middle Logan Creek	#1 Lower Logan Creek	
		7.73	8.27	8.35	8.15	7.70	7/16/75
		7.93	8.15	8.40	8.46	7.92	7/30/75
	7.51	7.65	8.00	8.01	8.16	7.88	8/12/75
	7.43	7.78	8.02	8.03	8.24	7.93	8/27/75
7.66	7.72	8.01	8.02	7.91	8.01	7.85	9/3/75
7.95	7.69	7.78	8.00	8.02	8.21	7.91	9/22/75
						7.63	4/7/76
8.21	7.26	8.48	8.51	8.07	8.25	7.47	5/6/76
7.78	6.13	6.72	7.01	7.76	7.93	7.50	5/13/76
8.08	6.58	6.77	7.24	7.96	8.06	7.73	5/21/76
8.20	6.80	7.00	7.57	8.29	7.93	7.93	6/3/76
8.55	6.53	7.08	7.19	8.23	8.47	8.07	6/17/76
8.19	6.63	6.88	7.57	8.26	8.37	8.07	7/3/76
8.19	6.51	6.88	7.59	8.19	8.40	7.87	7/9/76
8.31	6.71	6.91	7.63	8.19	8.37	7.91	7/27/76
8.24	6.60	6.89	7.48	8.20	8.34	7.91	8/3/76
8.19	6.68	6.99	7.51	8.17	8.29	7.96	8/31/76
	6.70	6.73	7.66	8.02	8.18	7.87	9/28/76

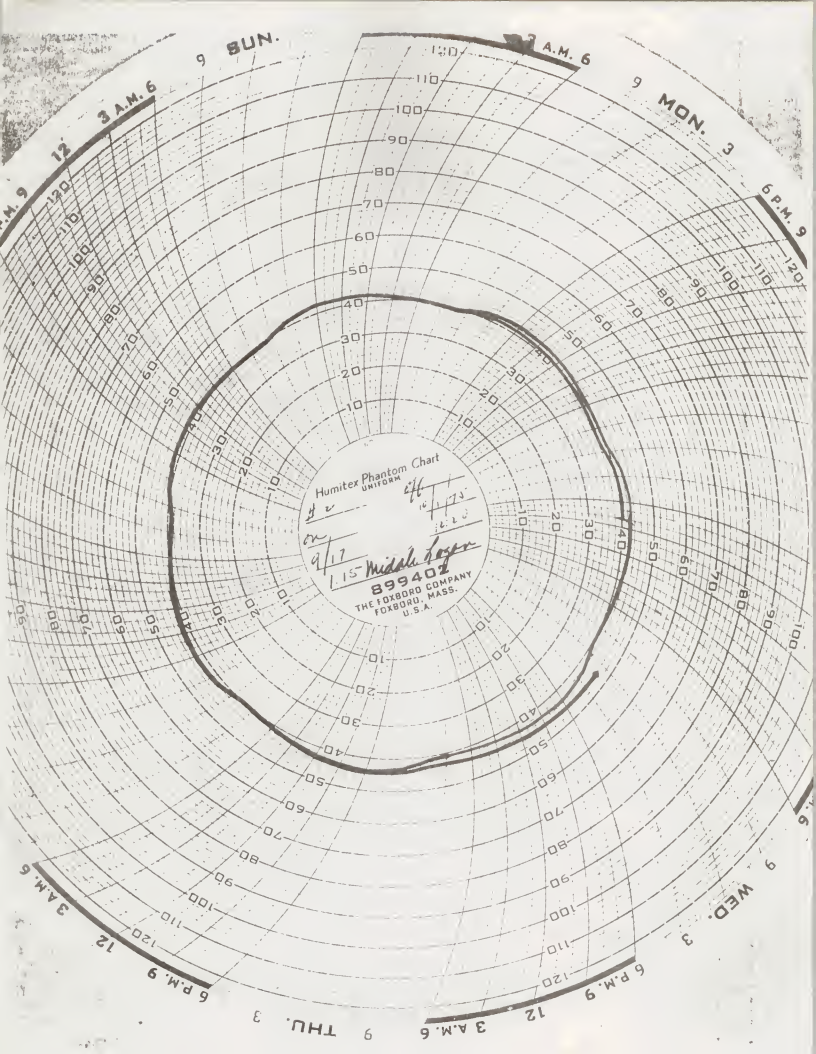
pH

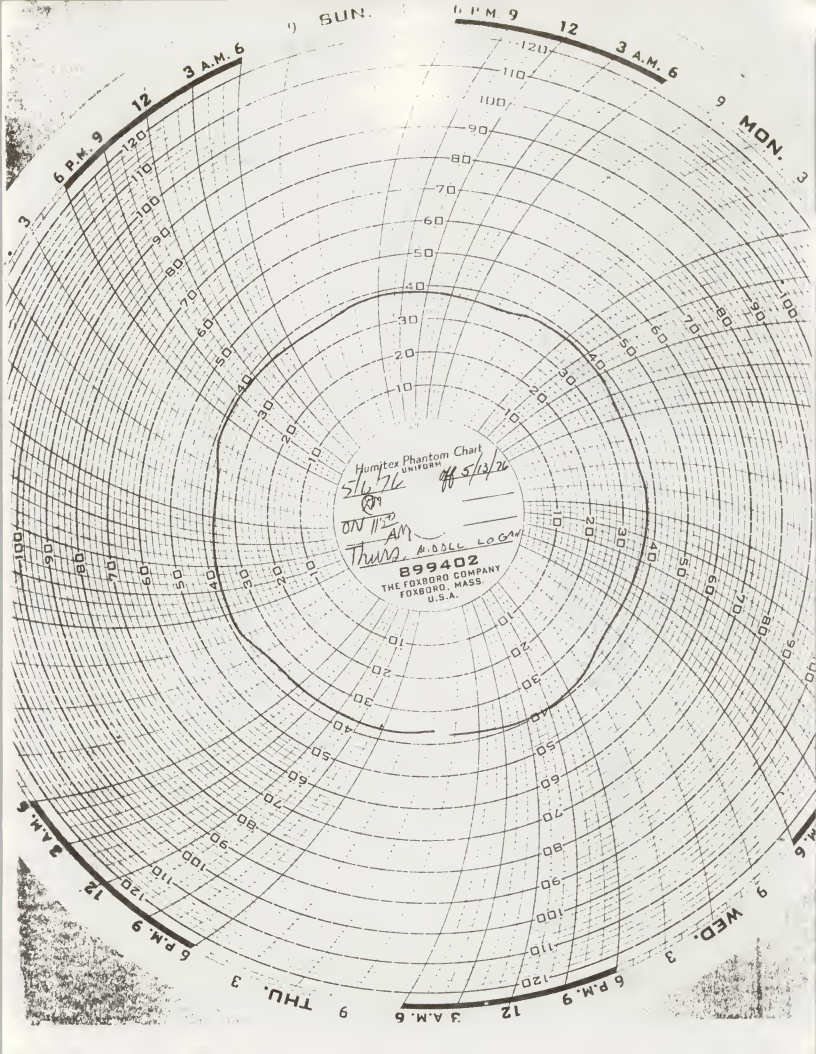
Date	#1 Lower Logan Creek	#2 Middle Logan Creek	#3 Upper Logan Creek	#4 Griffin Creek	#5 Lower Hand Creek	#6 Upper Hand Creek
7/16/75	55.0	15.0	7.5	12	6	4
7/30/75	41.8	10.8	5.6	7.8	3.1	2.3
8/12/75	29	10	3	15	4	2
8/27/75	26	8	2.7	14	3.5	1.7
9/3/75	26	8	2.7	14.5	3	1.6
9/22/75	22	8	2.6	14.3	2.8	1.7
4/7/76						
5/6/76		77	40		75	32
5/13/76		130	74		92	52
5/21/76		97	36		72	38
6/3/76	193	28	13	52		10
6/17/76	156	32	11	77	14	4
7/3/76	60	26	8	62	11	3
7/9/76	60	28	8	60	11	3
7/27/76	48	23	2.5	38	8	2
8/3/76	41	26		15	4	2
8/31/76	39	21	2.0		4	1.5
9/28/76	34	20	2.0	9	4	1.3

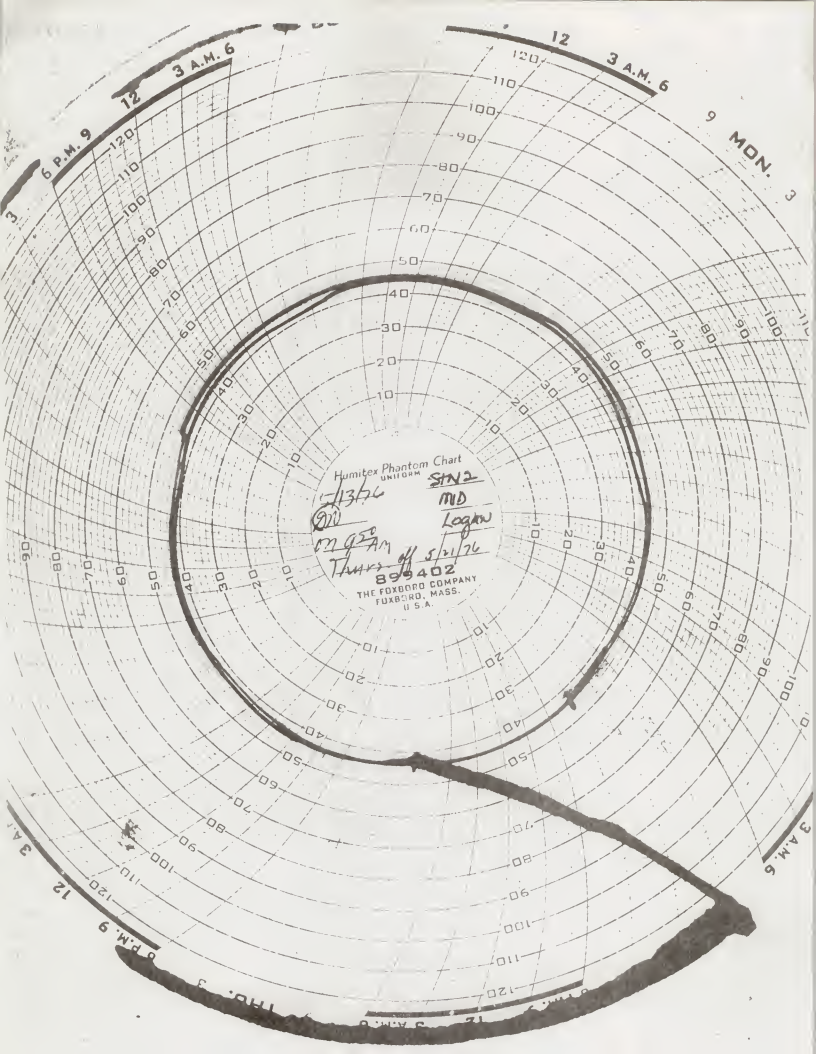
FLOW

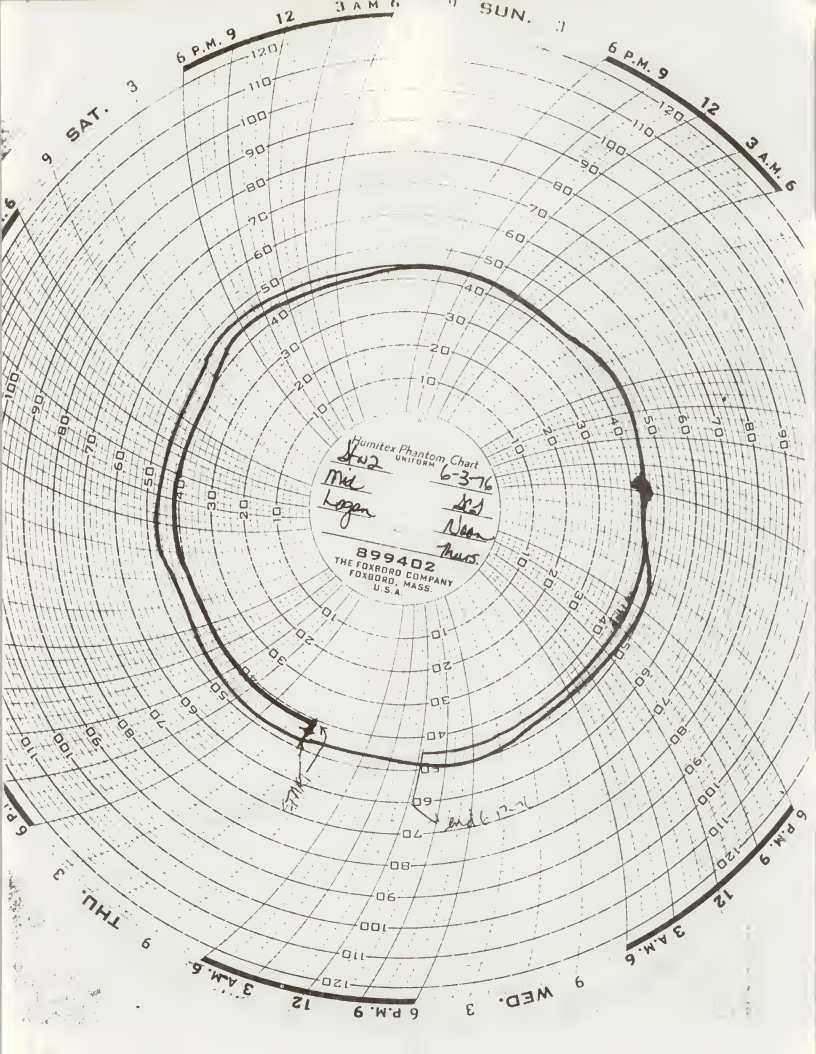

Humitex Pheatron Chart
UNIT 2SN
6/25
7/30/75
Middle Logan Ct.
899202
THE FOXBORO COMPANY
FOXBORO, MASS.
U.S.A.
6 P.M. 9 12 3 A.M. 6
9 MON. 3
9 THU. 3
9 WED. 3

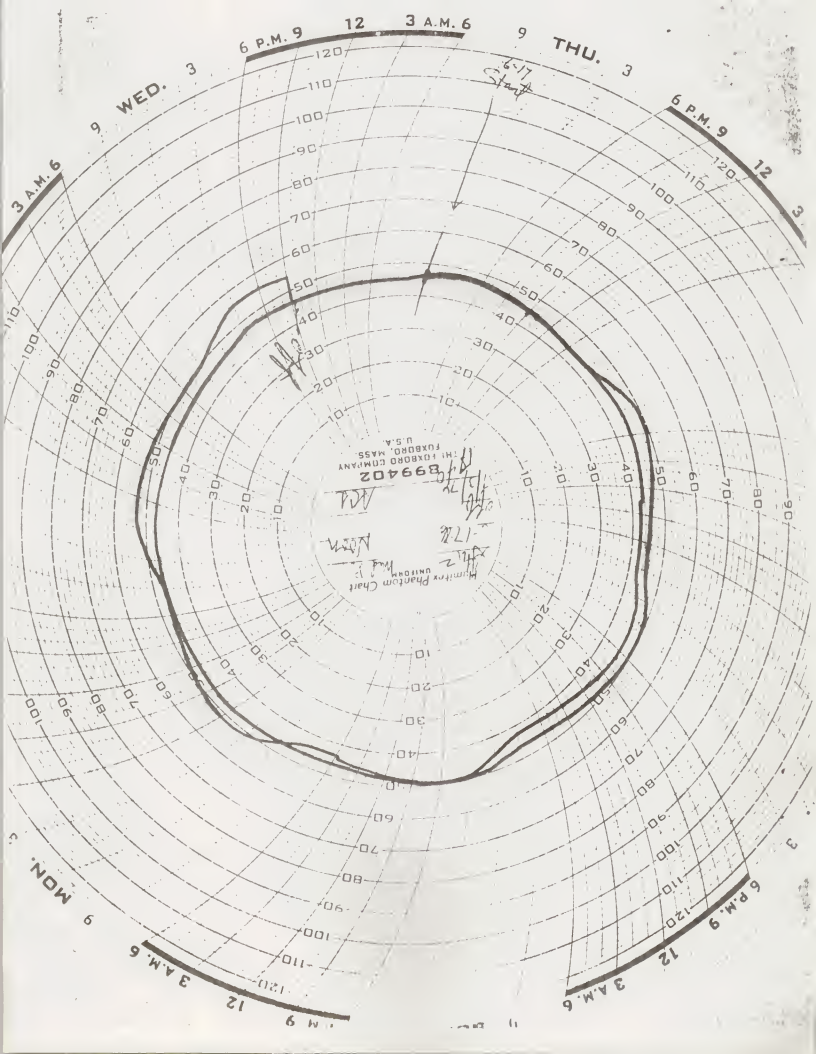

Humitex Phantom Chart
UNIFORM
899402
THE FOXBORO COMPANY
FOXBORO, MASS.
U.S.A.
6 P.M. 9
12
3 A.M. 6
SAT. 3
THU. 3
WED. 3

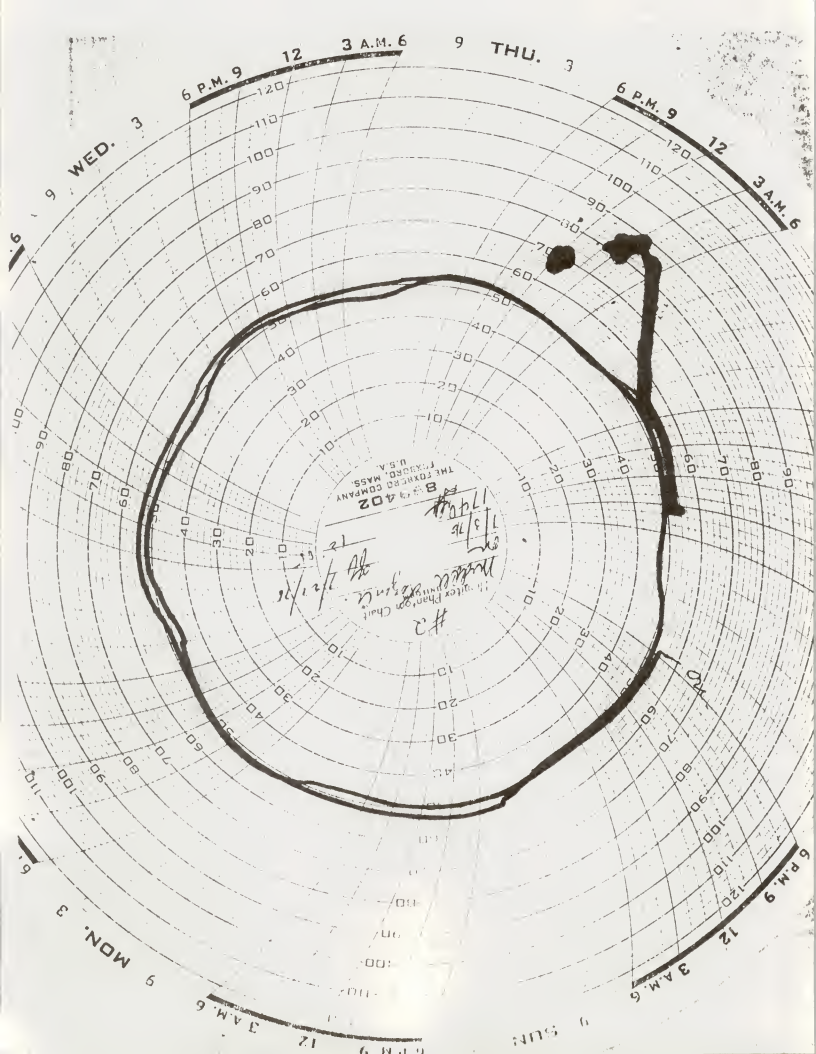

SUN.
MON.
TUE.
WED.
THU.
A.M.
P.M.
Humiter Phantom Chart
UNIFORM
89940
THE FOXBORO COMPANY
FOXBORO, MASS.
U.S.A.

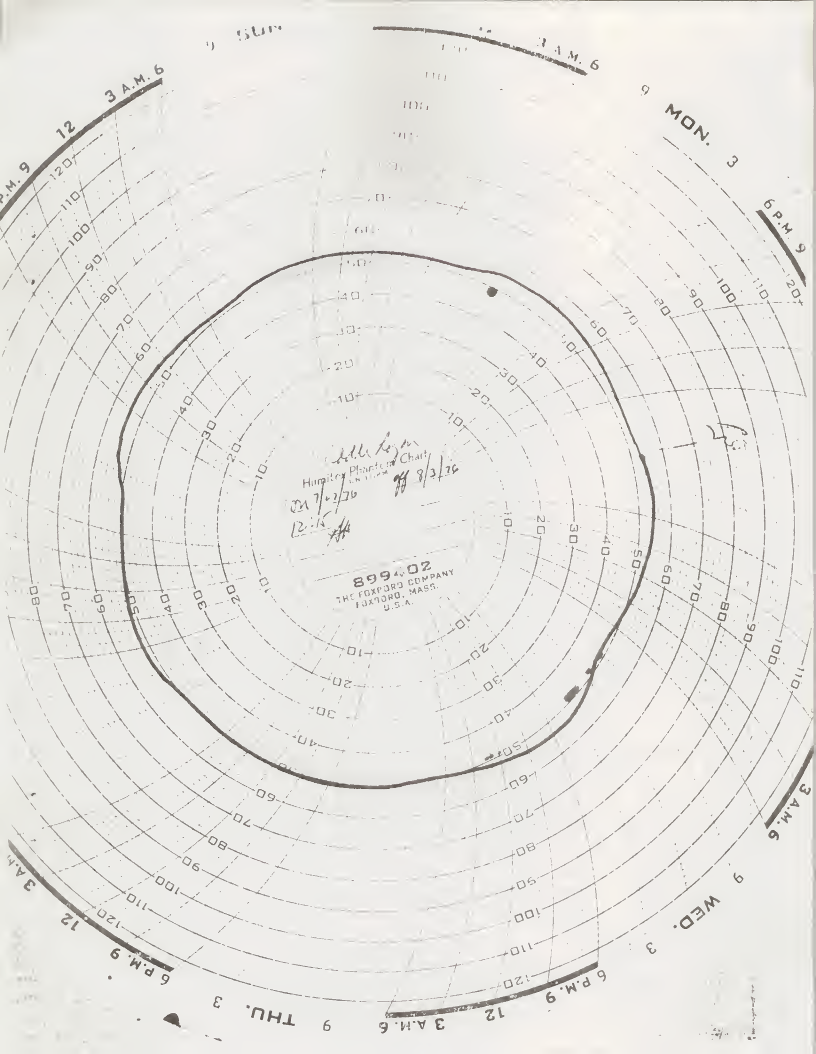

SUN.
MON.
TUE.
WED.
THU.
6 P.M. 9
12
3 A.M. 6
120
110
100
90
80
70
60
50
40
30
20
10
Humitex Phantom Chart
UNIFORM
5/6/76
5/13/76
ON 11:30 AM
THURS. MIDDLE LOOP
899402
THE FOXBORO COMPANY
FOXBORO, MASS.
U.S.A.


Humitex Phantom Chart
UNIFORM
SN2
MD
Logan
5/1/76
THE FOXBORO COMPANY
FOXBORO, MASS.
U.S.A.
12
3 A.M.
6
9 MON.
6 P.M.

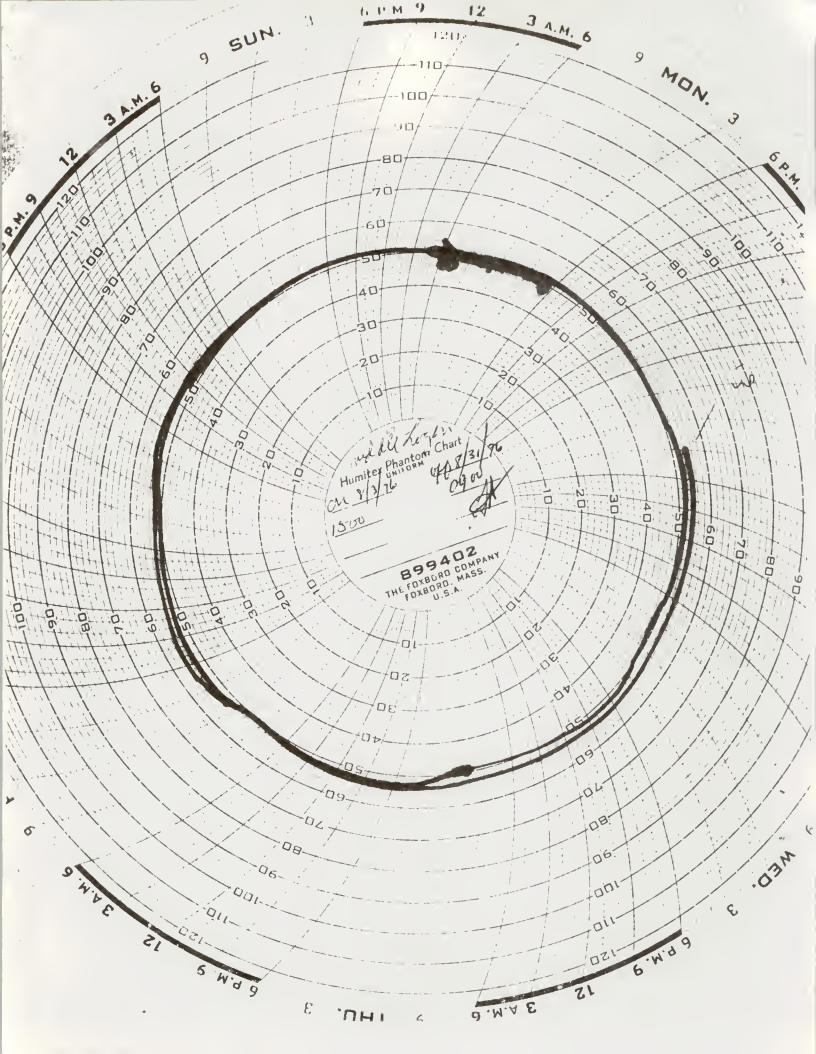

Humitex Phantom Chart
UNIFORM
899402
THE FOXBORO COMPANY
FOXBORO, MASS.
U.S.A.
SUN.
MON.
TUES.
WED.
THU.
SAT.
6 P.M.
9
12
3 A.M.
6

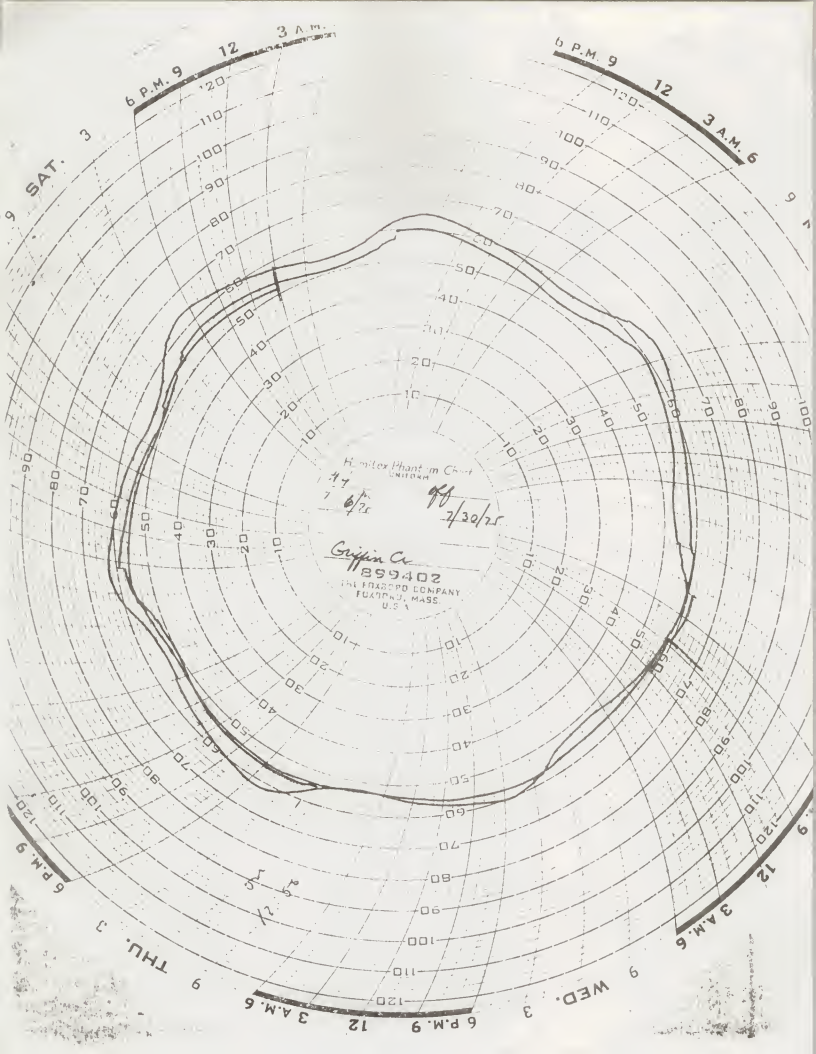

6 P.M. 9 12 3 A.M. 6 9 THU. 3
6 P.M. 9 12 3 A.M. 6 9 WED. 3
6 P.M. 9 12 3 A.M. 6 9 MON. 3
Start
Humphrey Phantom Chart
UNITORK
THE FOXBORO COMPANY
FOXBORO, MASS
U.S.A.
B99402

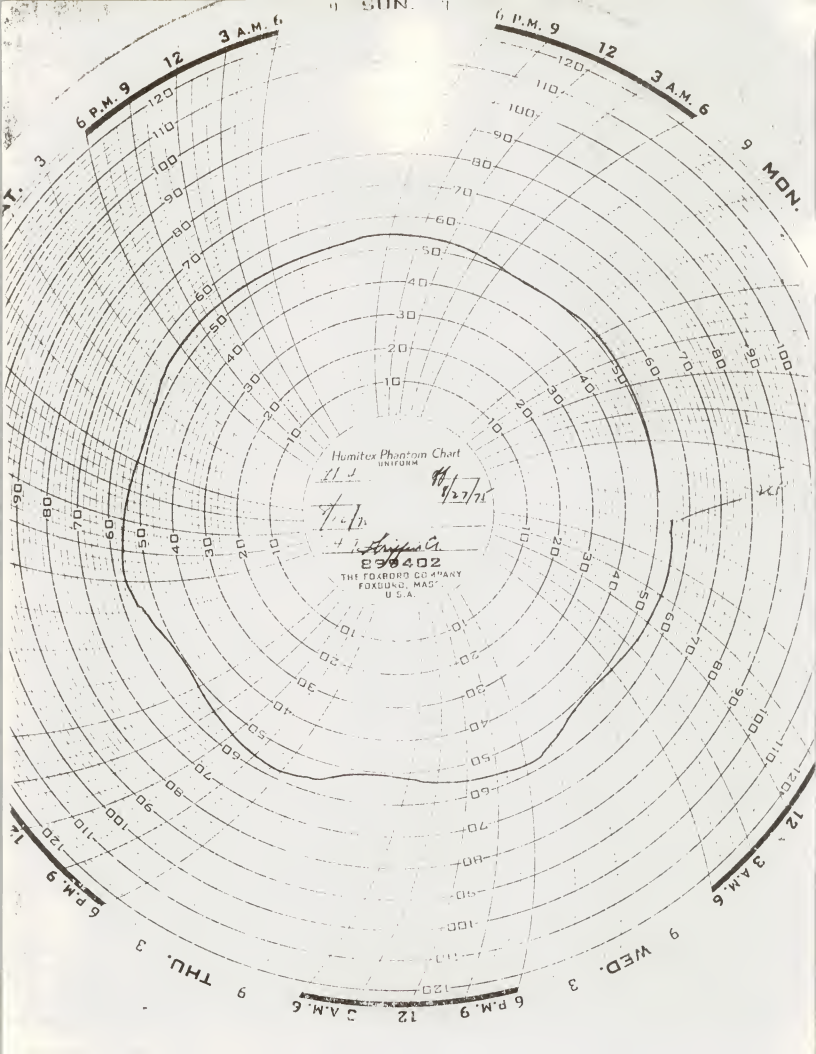

6 P.M. 9 12 3 A.M. 6 9 THU. 3
6 P.M. 9 12 3 A.M. 6
9 WED. 3
9 MON. 3
9 SUN.
THE FOXBORO COMPANY
FOXBORO, MASS.
U.S.A.

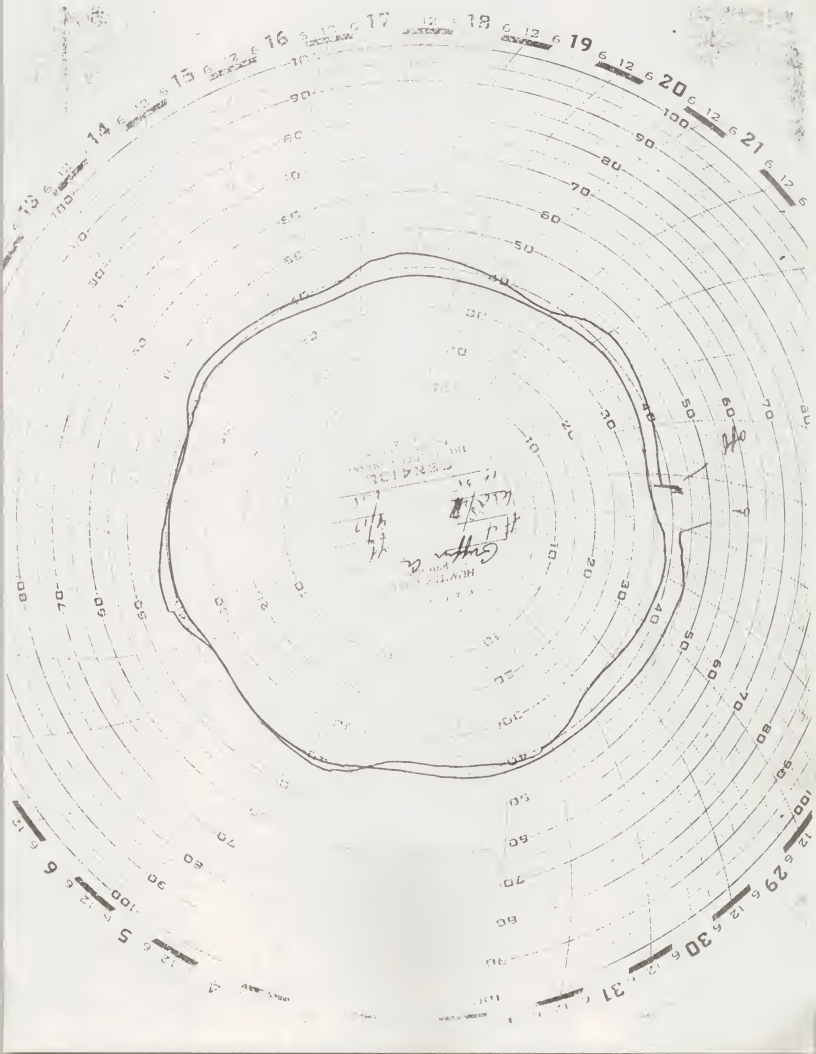


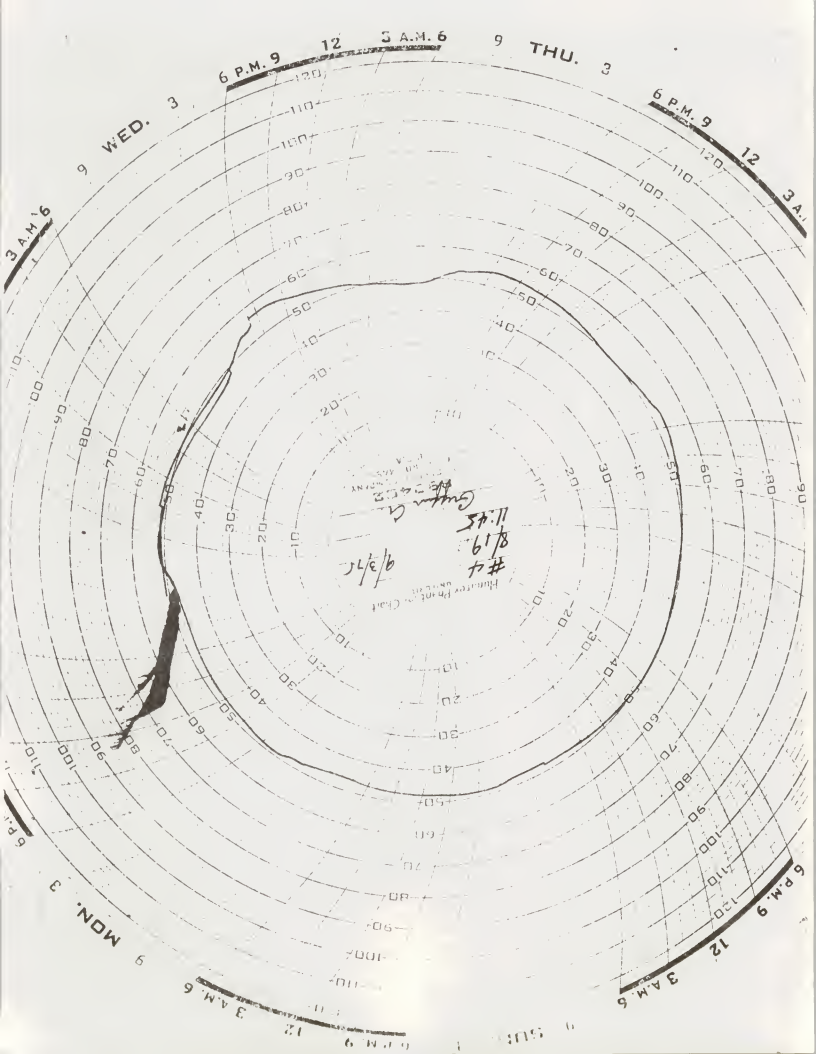
Humitex Phantom Chart
899402
THE FOXBORO COMPANY
FOXBORO, MASS.
U.S.A.
MON.
WED.
THU.
3 A.M. 6
6 P.M. 9

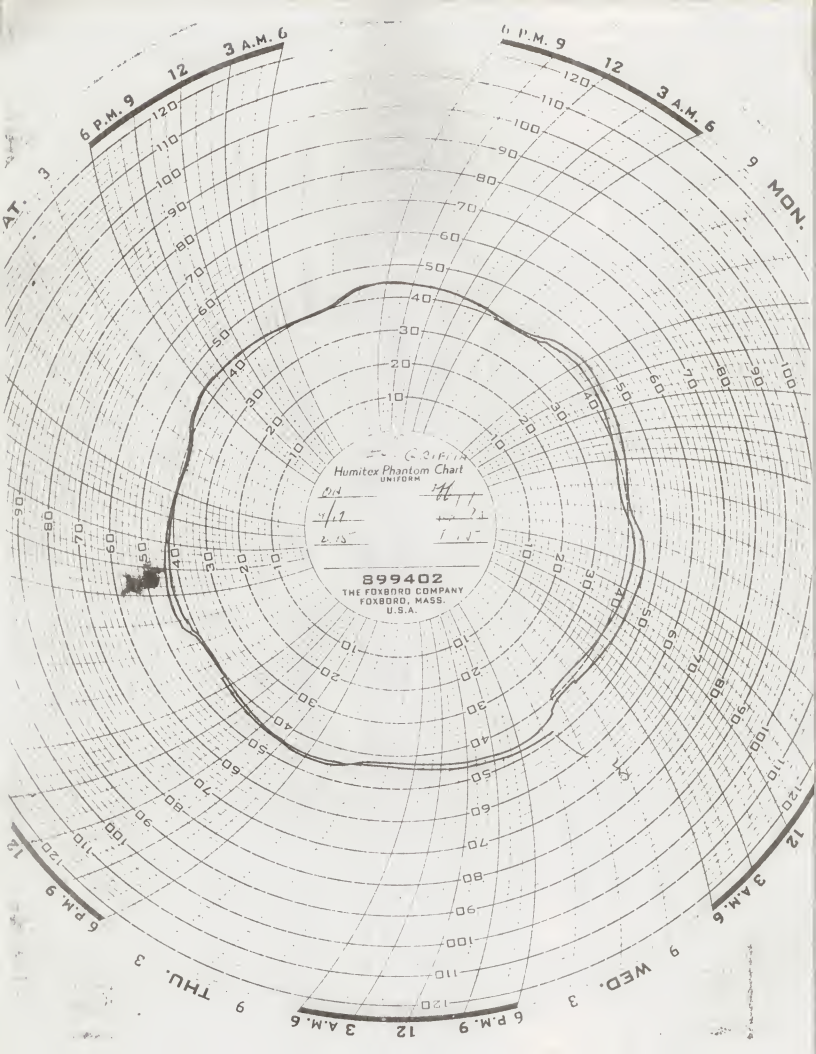

SUN.
MON.
TUE.
WED.
THU.
6 P.M.
12
3 A.M.
6 P.M.
12
3 A.M.
Humiter Phantom Chart
UNIFORM
899402
THE FOXBORO COMPANY
FOXBORO, MASS.
U.S.A.

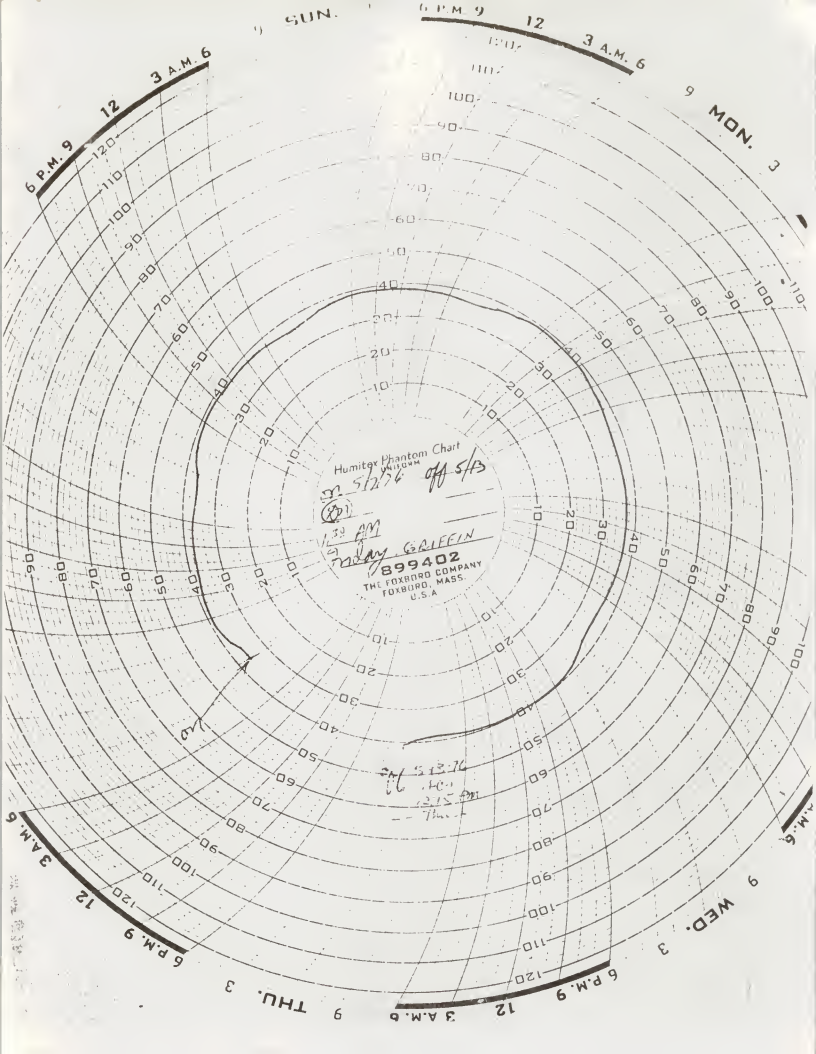

6 P.M. 9 12 3 A.M. 6
9 SAT. 3
6 P.M. 9 12 3 A.M. 6
9 THU. 3
6 P.M. 9 12 3 A.M. 6
9 WED. 3
6 P.M. 9 12 3 A.M. 6
899402
INSTRUMENTS COMPANY
FRANKLIN, MASS.
U.S.A.
2/30/25

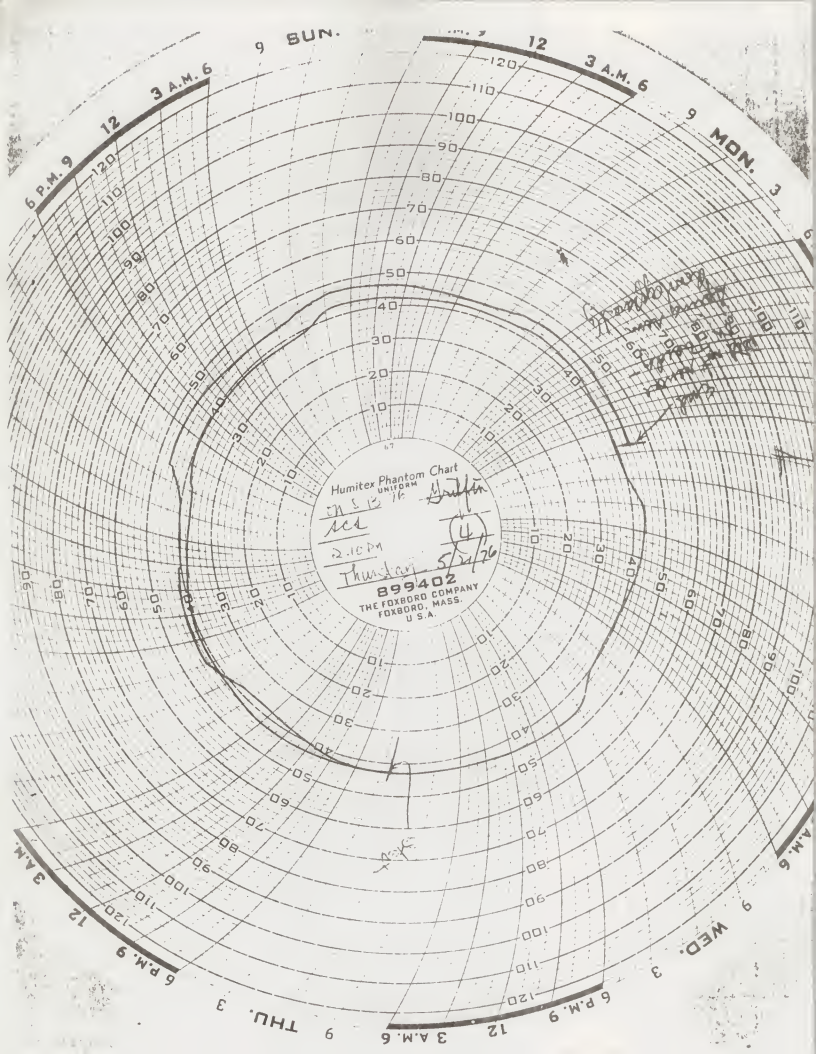

SUN.
6 P.M. 9
12
3 A.M. 6
9 MON.
3
Humitex Phantom Chart
UNIFORM
11/27/71
89402
THE FOXBORO COMPANY
FOXBORO, MASS.
U.S.A.
9 TUE.
9 WED.
9 THU.
120
110
100
90
80
70
60
50
40
30
20
10

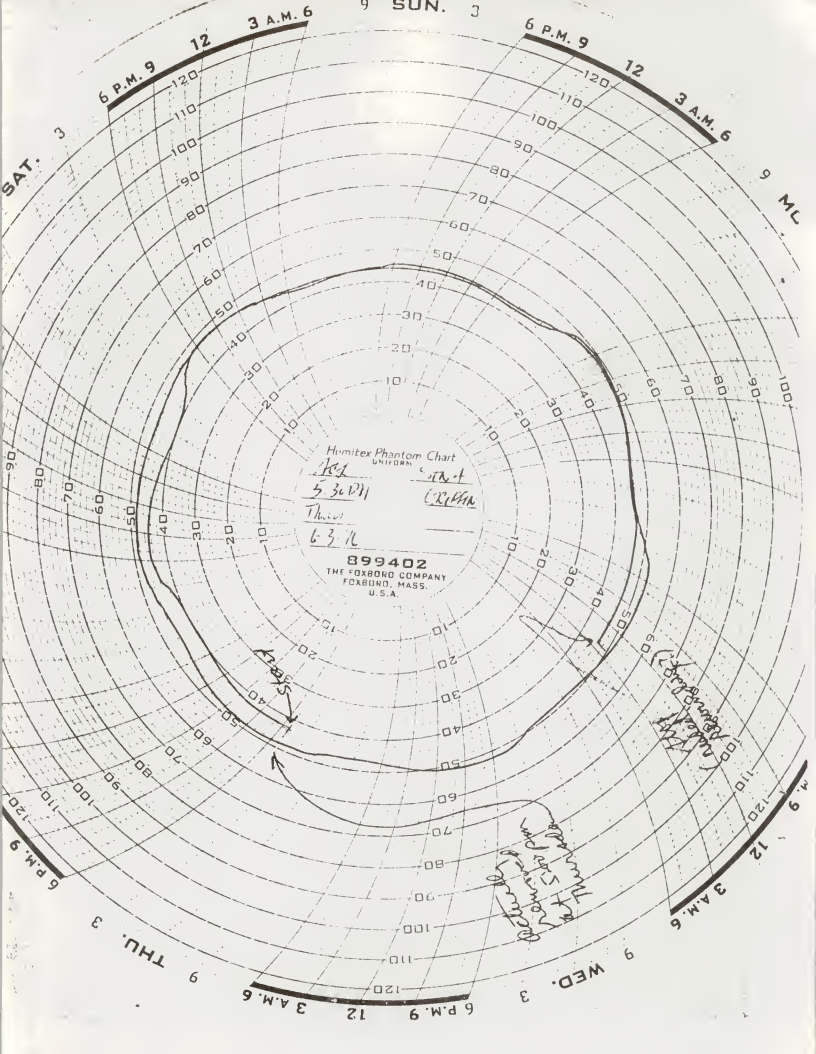


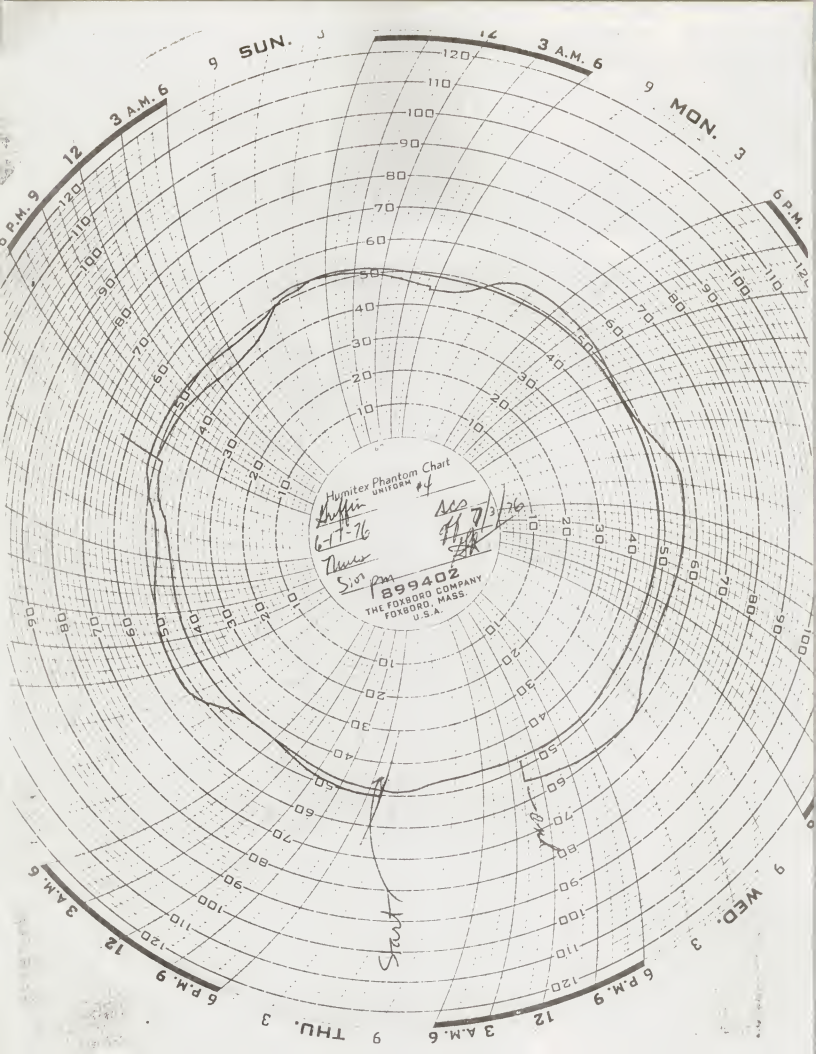

6 P.M. 9 12 3 A.M. 6 9 THU. 3
6 P.M. 9 12 3 A.M.
9 WED. 3
3 A.M. 6
6 P.M. 9 12 3 A.M. 6
9 MON. 3
6 P.M.
9 SUN.

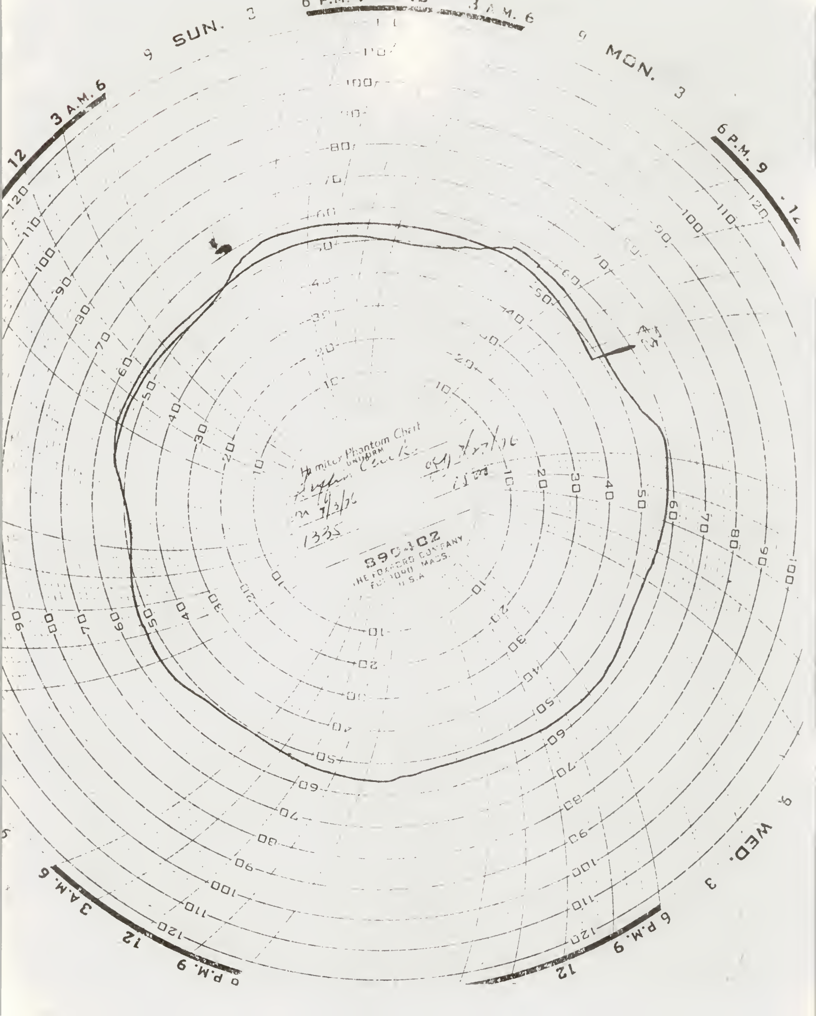

6 P.M. 9
12
3 A.M. 6
120
110
100
90
80
70
60
50
40
30
20
10
Humitex Phantom Chart
UNIFORM
899402
THE FOXBORO COMPANY
FOXBORO, MASS.
U.S.A.
MON.
SAT. 3
THU. 3
WED. 3


SUN.
MON.
TUE.
WED.
THU.
3 A.M.
6 P.M.
12
Humiter Phantom Chart
UNIFORM
899402
THE FOXBORO COMPANY
FOXBORO, MASS.
U.S.A.

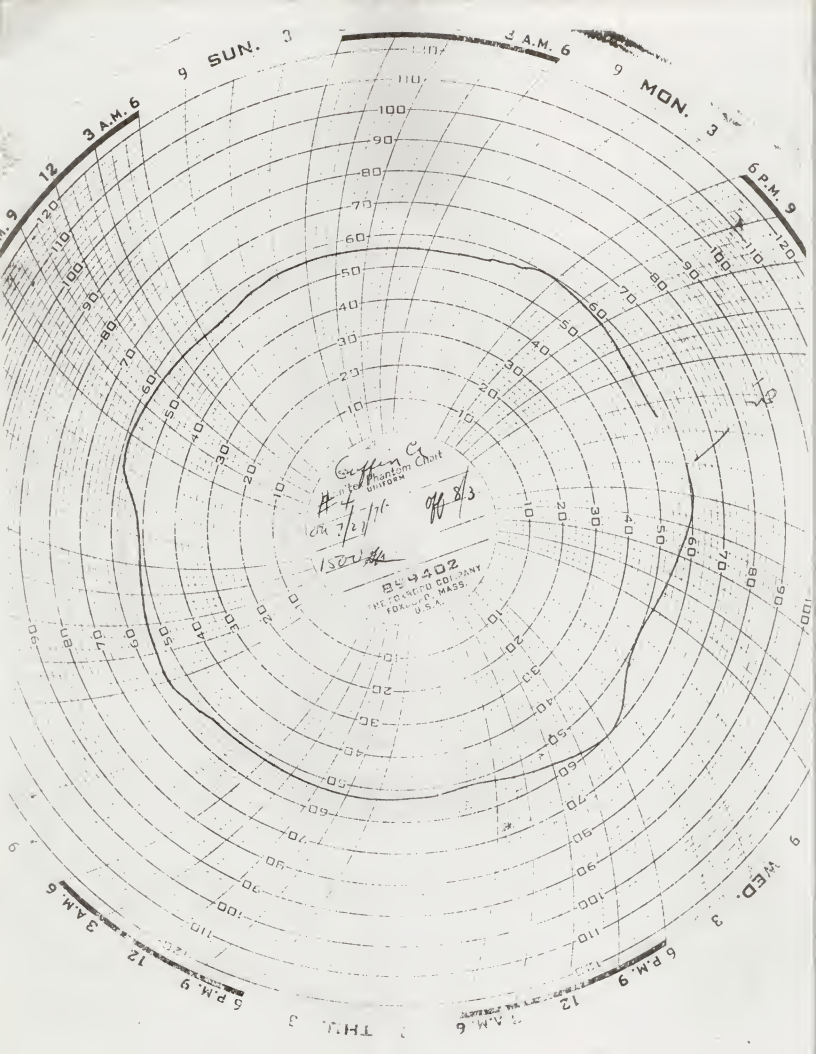

SUN.
MON.
TUE.
WED.
THU.
3 A.M.
6
9
12
3
6 P.M.
Humitex Phantom Chart
UNIFORM
899402
THE FOXBORO COMPANY
FOXBORO, MASS.
U.S.A.
Thursday
5/24/76

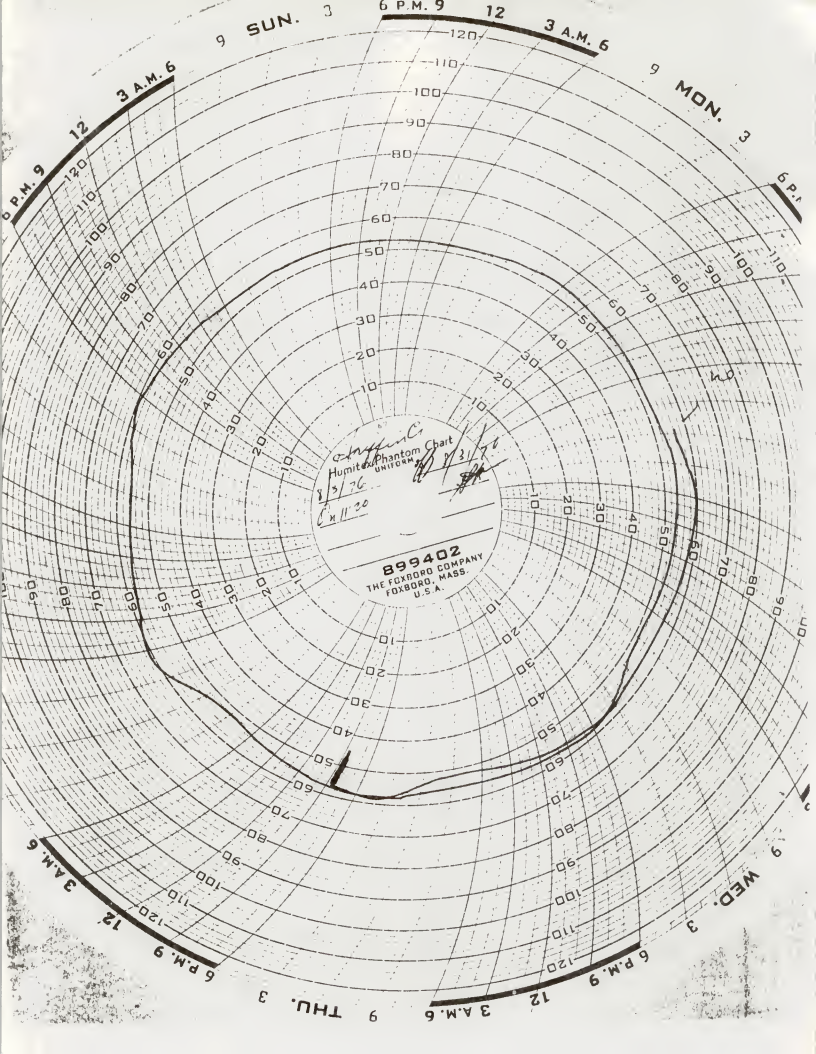

SUN.
MON.
TUE.
WED.
THU.
FRI.
SAT.
6 P.M.
9
12
3 A.M.
6
Homitex Phantom Chart
899402
THE FOXBORO COMPANY
FOXBORO, MASS.
U.S.A.

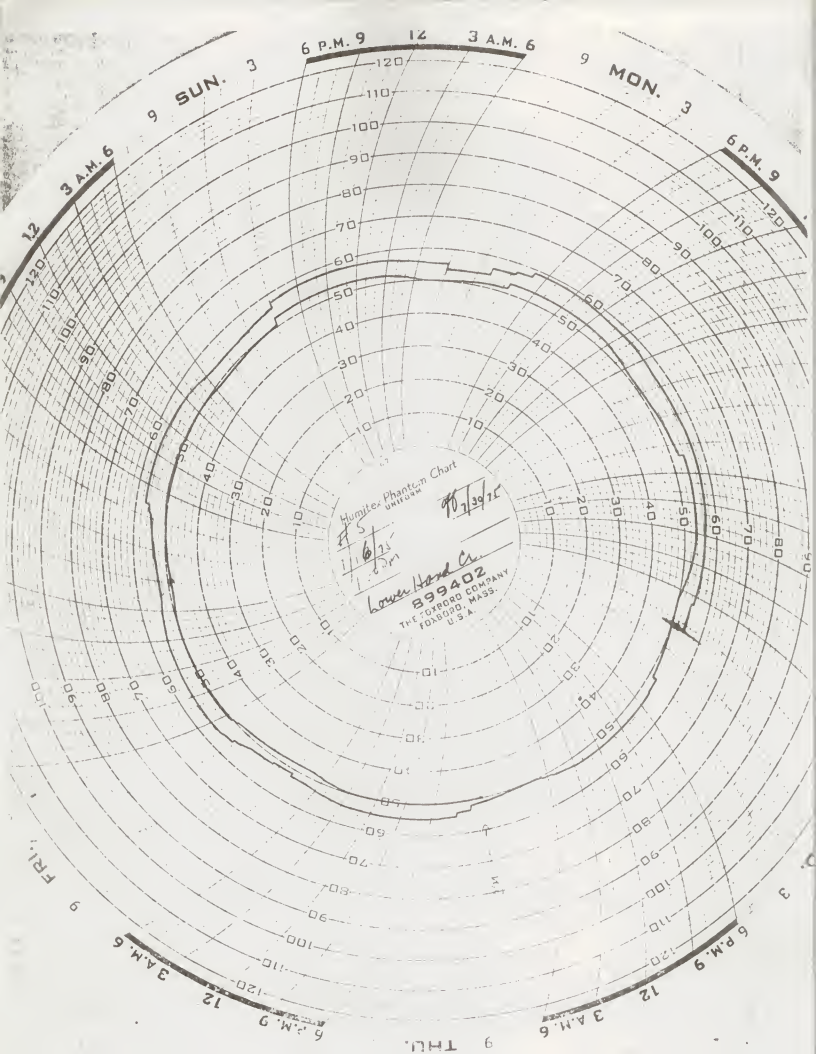

SUN.
MON.
TUE.
WED.
THU.
3 A.M.
6 P.M.
Humitex Phantom Chart
UNIFORM
6-7-76
899402
THE FOXBORO COMPANY
FOXBORO, MASS.
U.S.A.



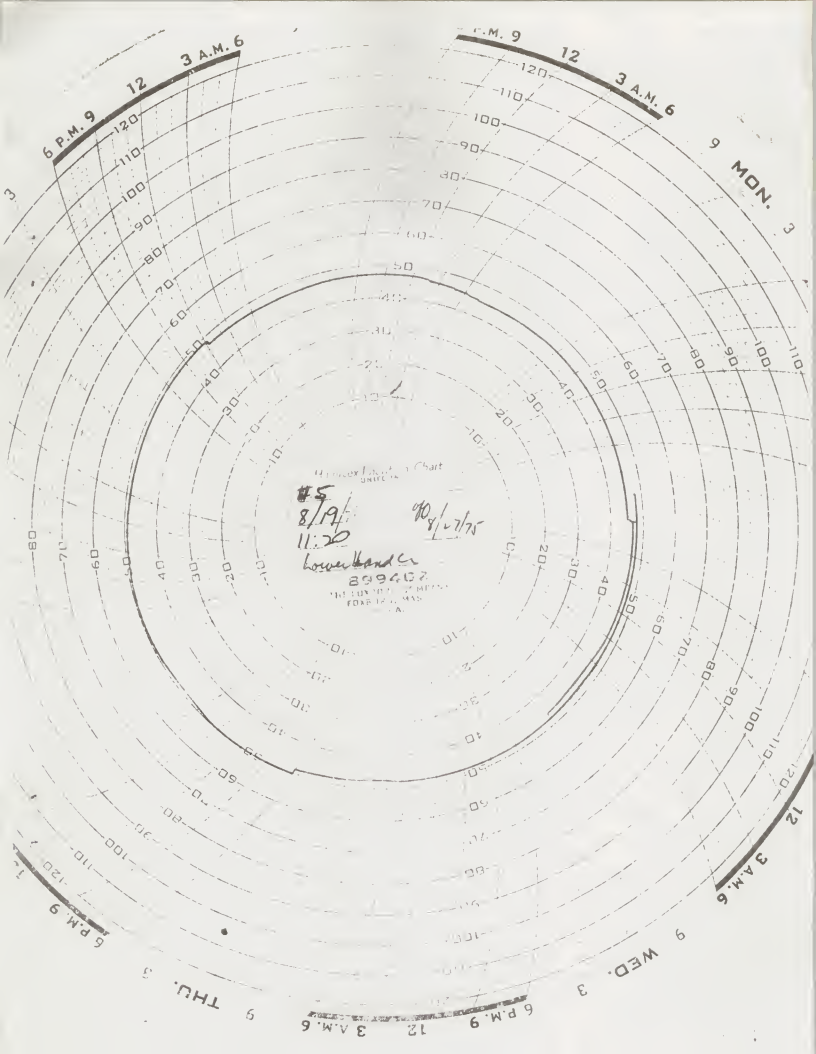
6 P.M. 9
12
3 A.M. 6
SUN.
MON.
WED.
THE FOXBORO COMPANY
FOXBORO MASS.
U.S.A.


SUN.
MON.
TUES.
WED.
THU.
3 A.M. 6
6 P.M. 9
12
Griffin Co.
Phantom Chart
UNIFORM
#4
7/2/14
#8/3
8549402
STANDARD COMPANY
FOXBORO, MASS.
U.S.A.

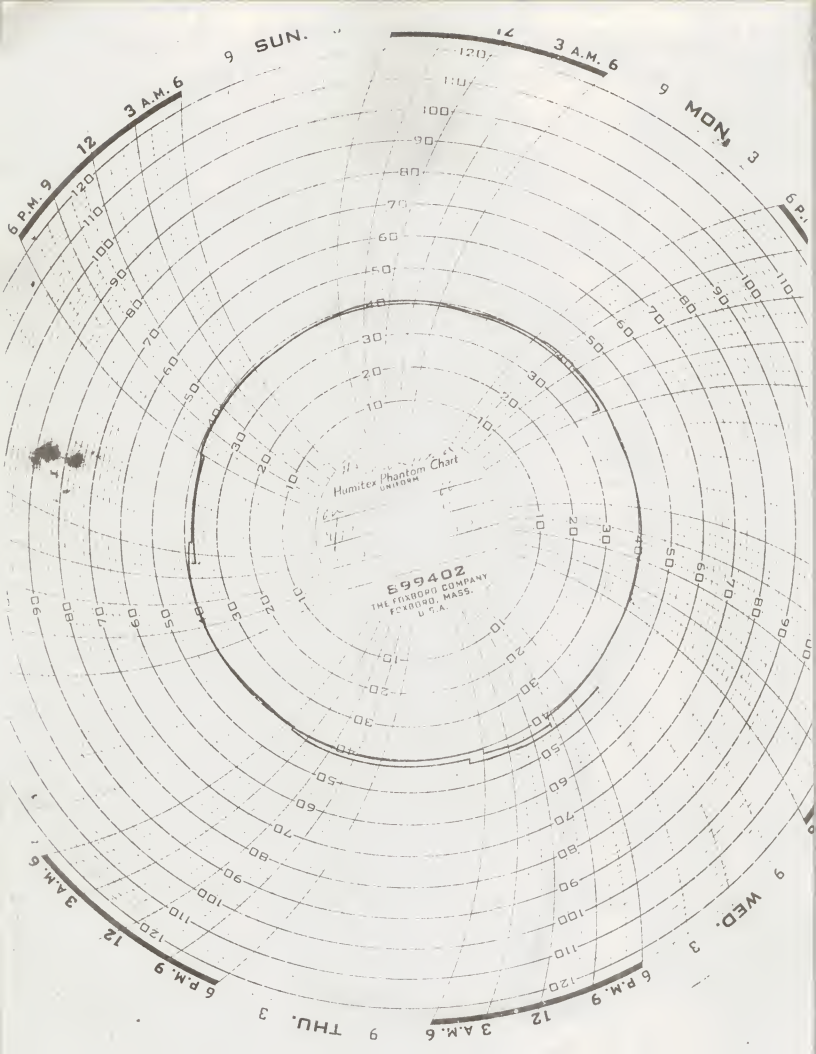

SUN.
MON.
TUE.
WED.
THU.
6 P.M.
12
3 A.M.
6
9
3
120
110
100
90
80
70
60
50
40
30
20
10
Humiter Phantom Chart
UNITORR
899402
THE FOXBORO COMPANY
FOXBORO, MASS.
U.S.A.

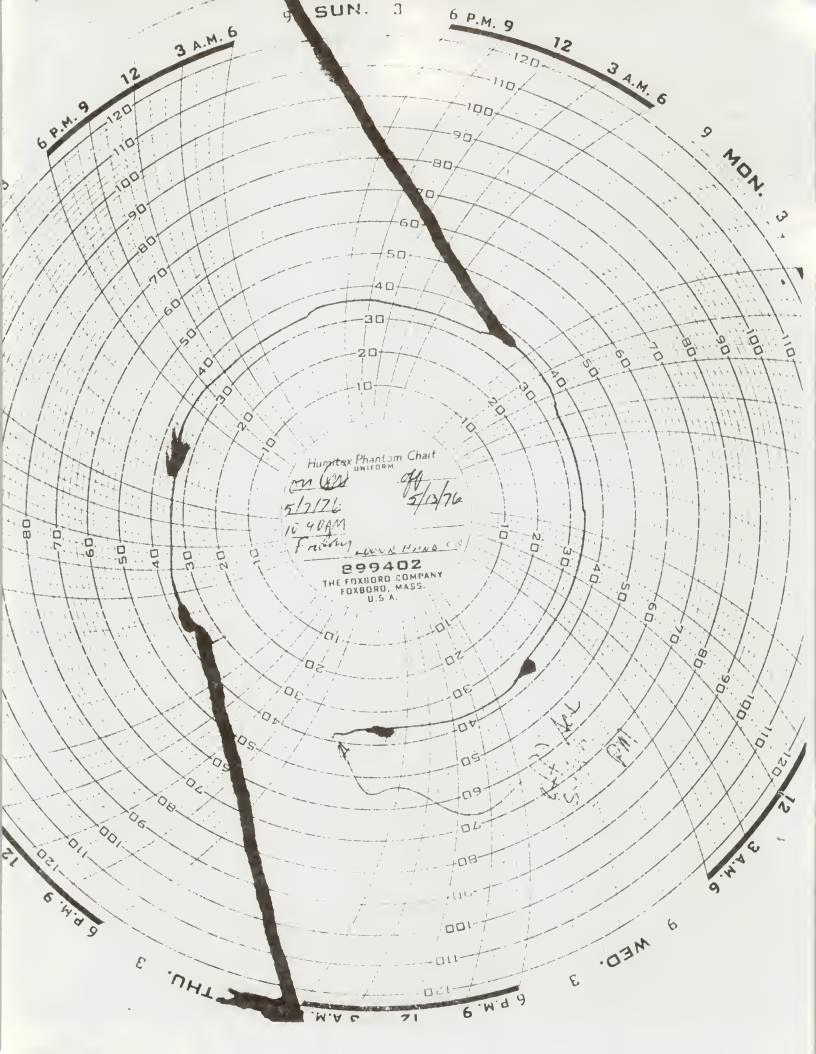

6 P.M. 9 12 3 A.M. 6
9 SUN. 3
9 MON. 3
6 P.M. 9
3 A.M. 6
12
120
110
100
90
80
70
60
50
40
30
20
10
Humitemp Phantom Chart
UNITRON
90 1 30 PT
Lower Hand Ch.
899402
THE FOXBORO COMPANY
FOXBORO, MASS.
U.S.A.
9 FRI.
9 THU.

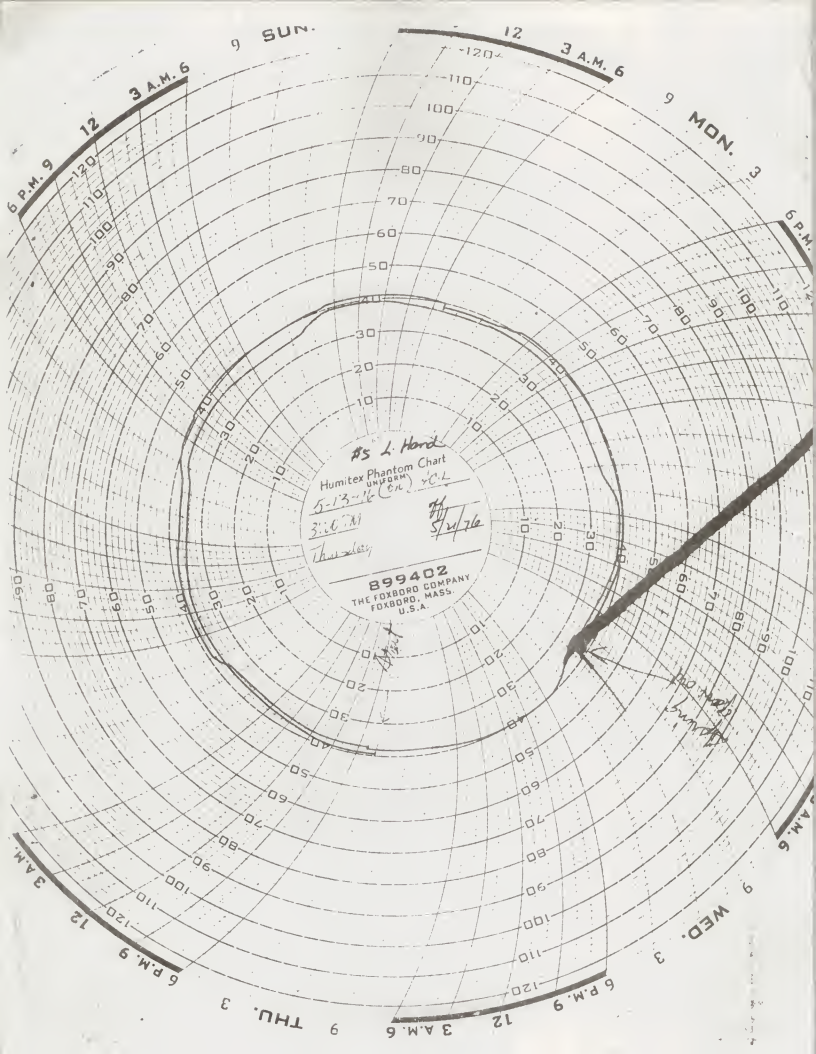
SUN.
MON.
WED.
THU.
6 P.M.
12
3 A.M.
9
3
6
Humitex Phantom Chart
UNIFORM
899402
THE FOXBORO COMPANY
FOXBORO, MASS.
U.S.A.
Foxboro Co.

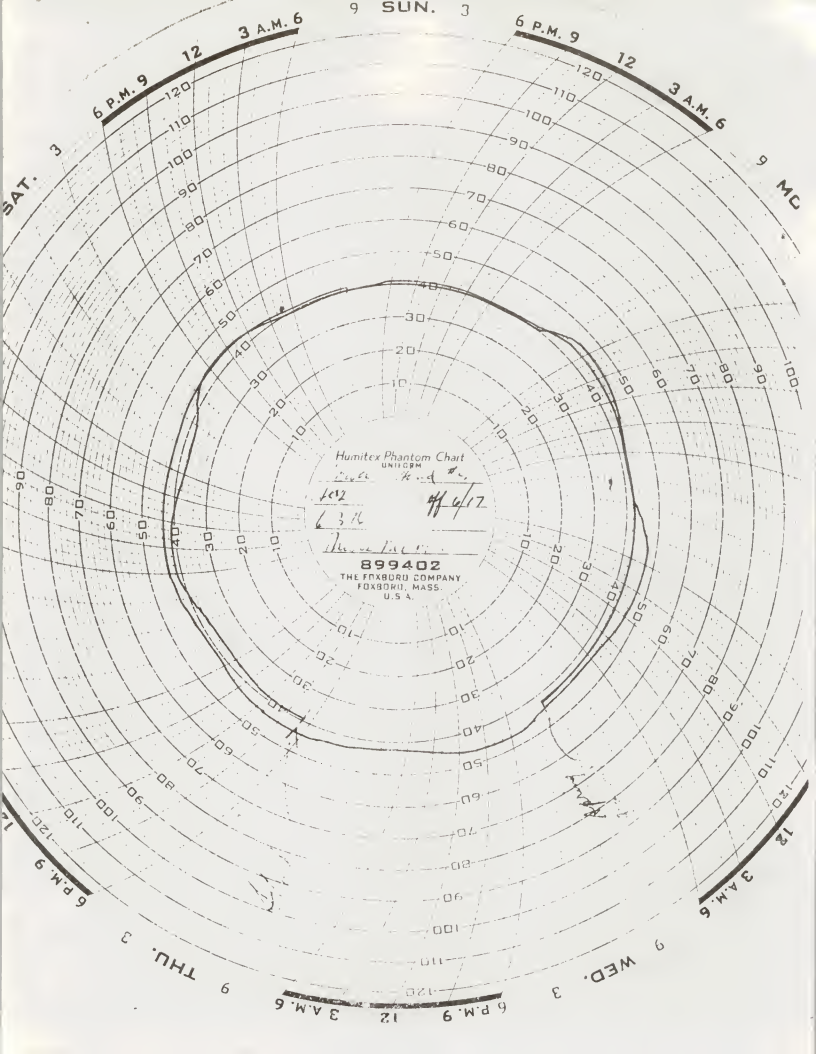

6 P.M. 9 12 3 A.M. 6
9 MON. 3
9 TUE. 3
9 WED. 3
9 THU. 3
#5
8/A
11:20
lower band
899402

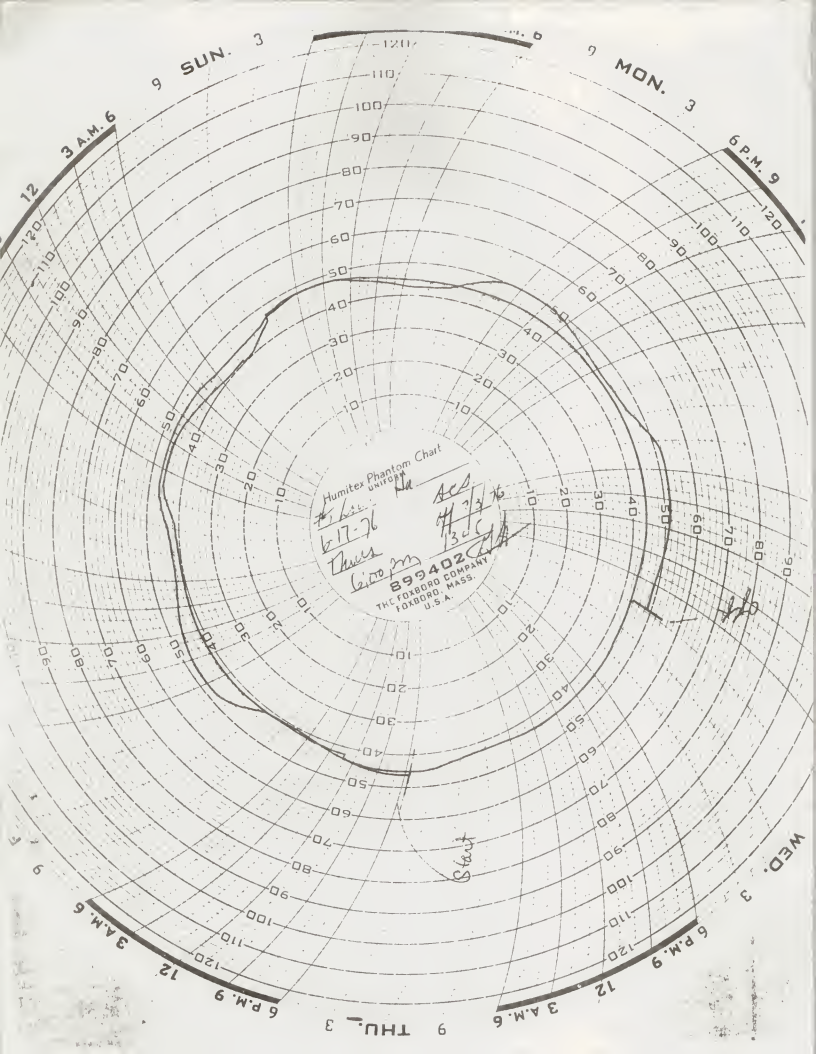
HUMITEX CHART
Lower Hand Cr

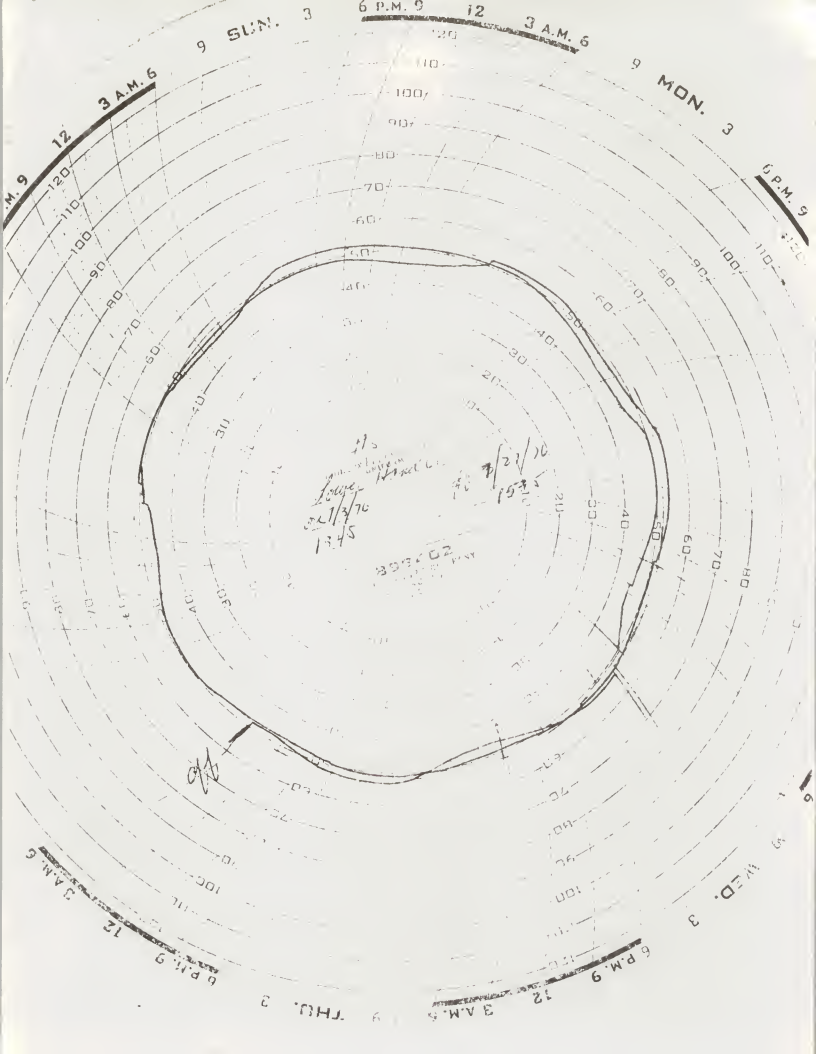

SUN.
MON.
TUE.
WED.
THU.
3 A.M.
6
9
12
3
6 P.M.
Humitex Phantom Chart
E99402
THE FOXBORO COMPANY
FOXBORO, MASS.
U.S.A.

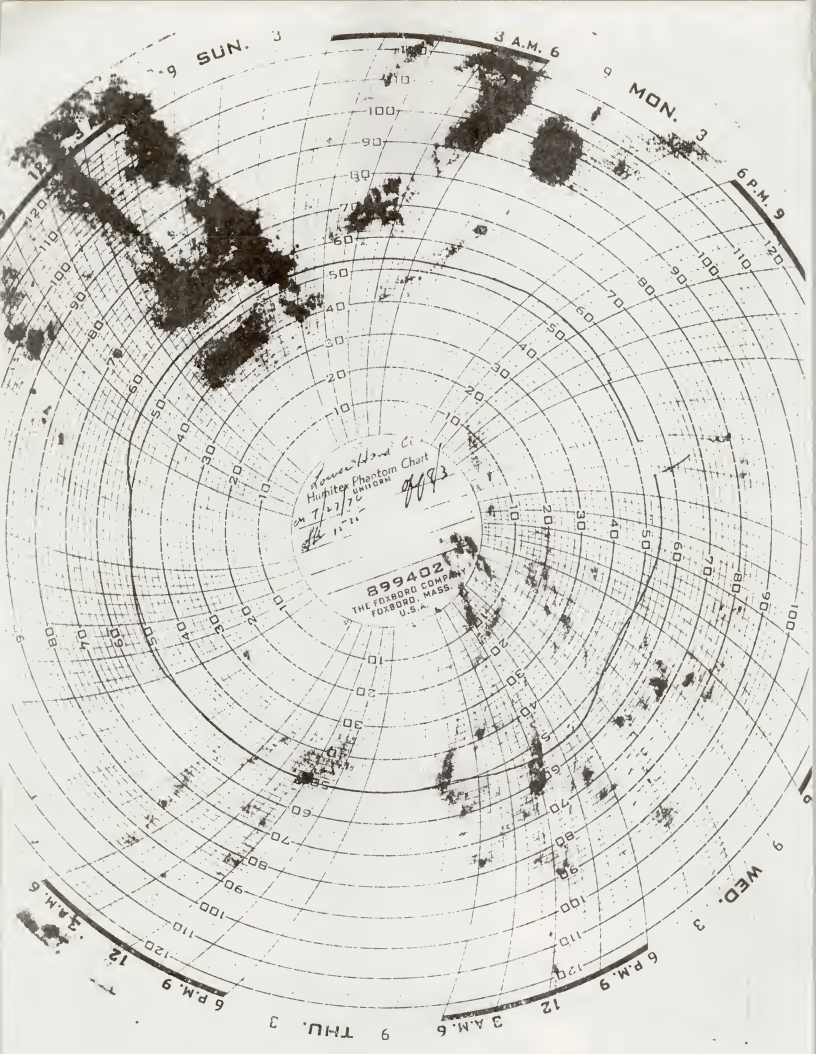

SUN.
MON.
TUES.
WED.
THU.
6 P.M.
9
12
3 A.M.
6
Humitex Phantom Chart
UNIFORM
5/7/76
10 40AM
899402
THE FOXBORO COMPANY
FOXBORO, MASS.
U.S.A.

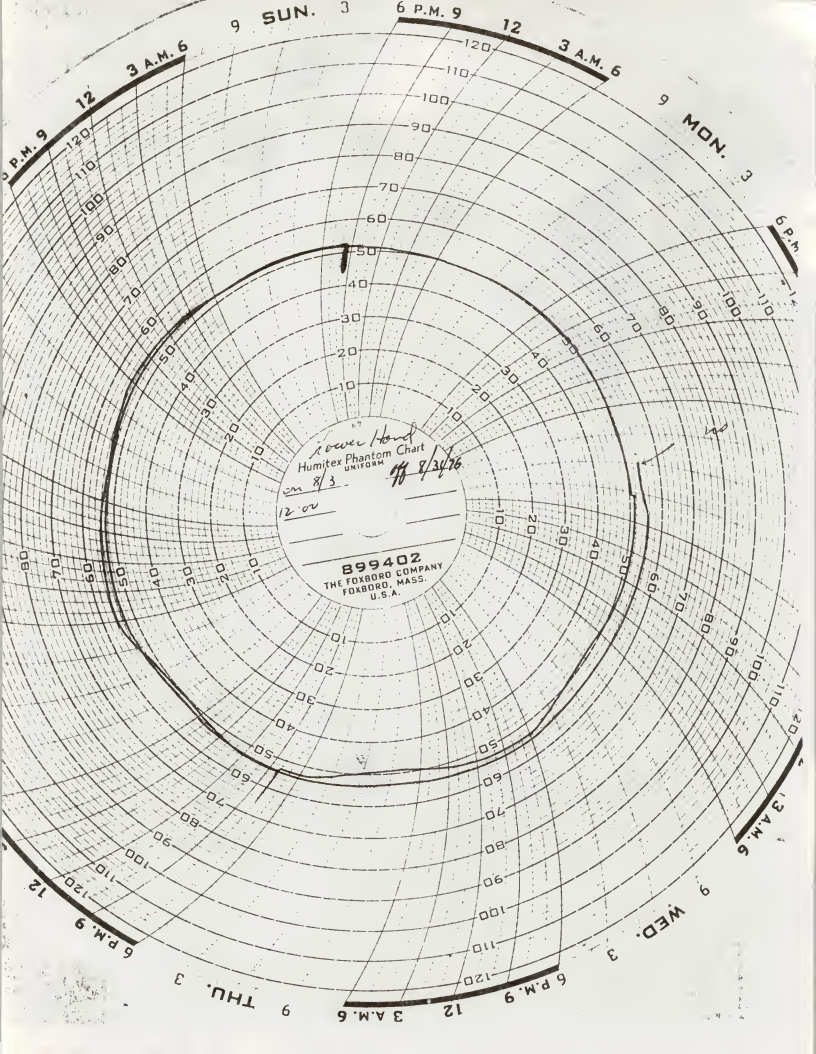

9 SUN.
12
3 A.M. 6
9 MON.
6 P.M.
9 TUE.
3
6 P.M. 9
12
3 A.M. 6
9 WED.
3
6 P.M. 9
12
3 A.M. 6
9 THU.
3
6 P.M. 9
12
3 A.M. 6
#5 L. Hood
Humitex Phantom Chart
UNIFORM
5-13-76 (Ex) VCL
3:16 PM
Thursday
5/14/76
899402
THE FOXBORO COMPANY
FOXBORO, MASS.
U.S.A.

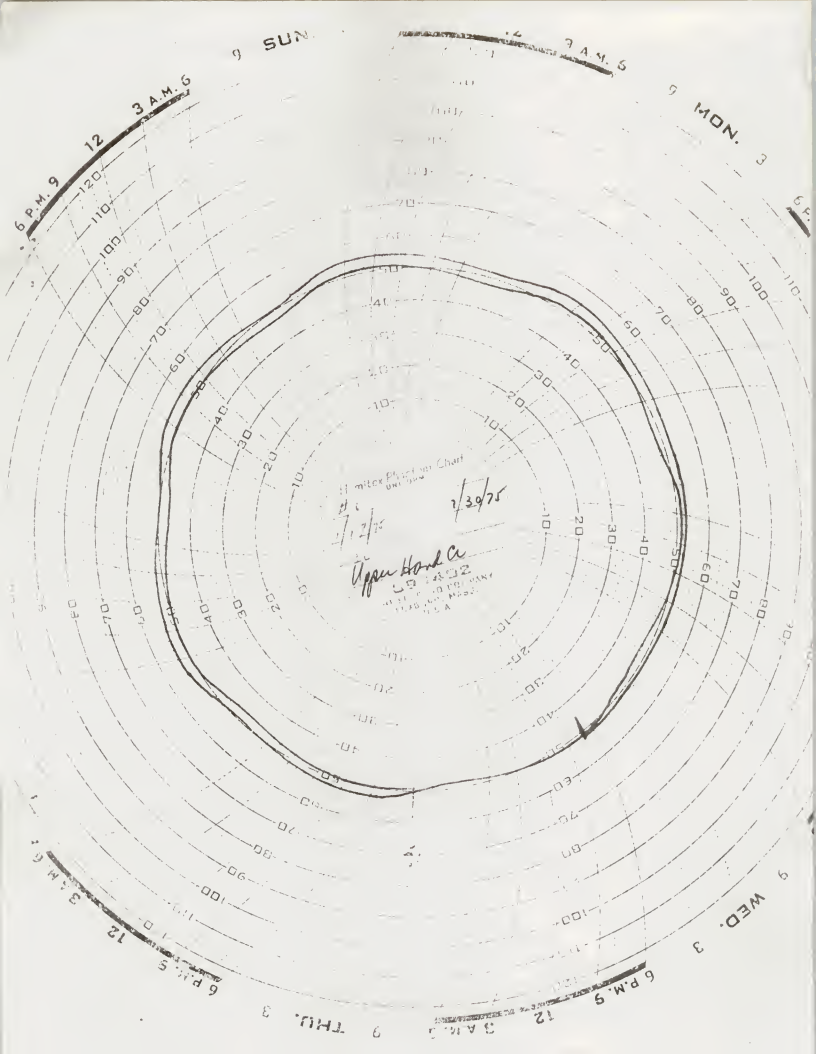

SUN.
MON.
TUE.
WED.
THU.
FRI.
SAT.
3 A.M.
6 P.M.
12
Humitex Phantom Chart
UNIFORM
899402
THE FOXBORO COMPANY
FOXBORO, MASS.
U.S.A.


SUN. 3
MON. 3
TUE. 3
WED. 3
THU. 3
12
3 A.M. 6
6 P.M. 9
Humitex Phantom Chart
UNIVERSAL
6-17-76
89402
THE FOXBORO COMPANY
FOXBORO, MASS.
U.S.A.

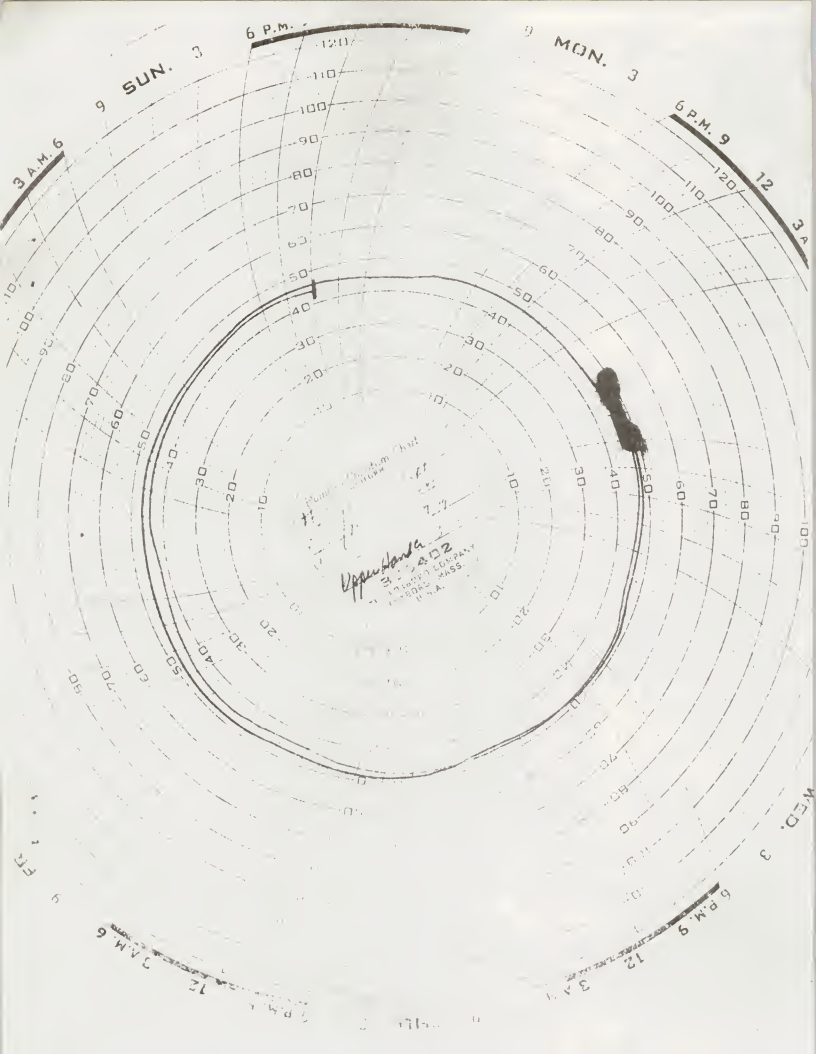

SUN.
MON.
TUES.
WED.
THU.
3 A.M.
6 P.M.
12
9
3
6
120
110
100
90
80
70
60
50
40
30
20
10

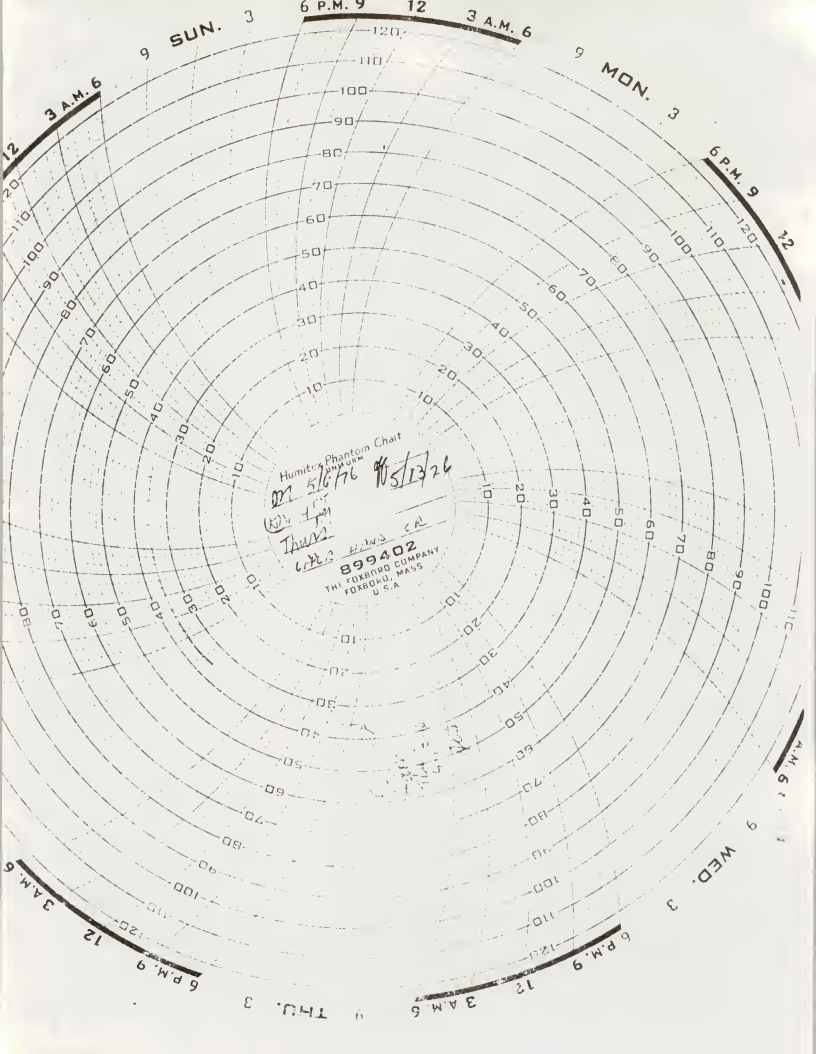

SUN.
MON.
TUE.
WED.
THU.
3 A.M.
6 P.M.
Humitex Phantom Chart
899402
THE FOXBORO COMPANY
FOXBORO, MASS.
U.S.A.

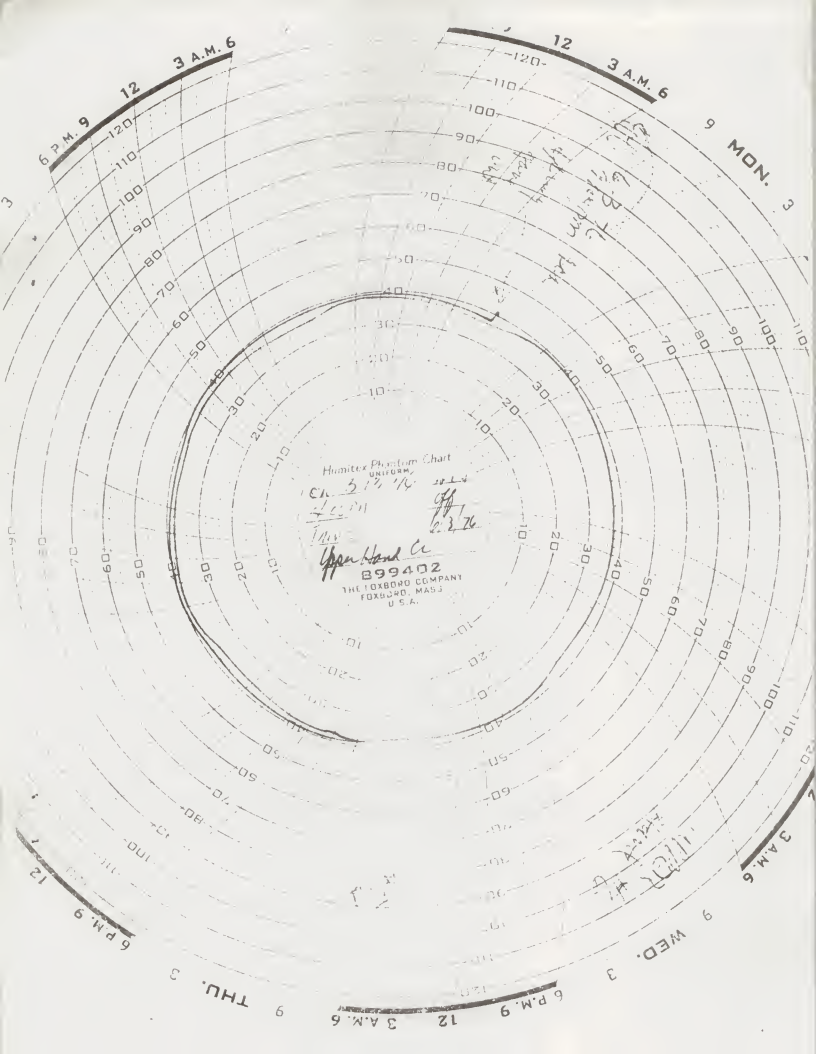

SUN.
MON.
TUE.
WED.
THU.
3 A.M.
6 P.M.
12
9
3
6
Tower Hood
Humitex Phantom Chart
UNIFORM
8/3
12 on
8/31/76
899402
THE FOXBORO COMPANY
FOXBORO, MASS.
U.S.A.


SUN
MON.
TUES.
WED.
THU.
3 A.M.
6 P.M.
12
9
1/30/75
Upper Hand Co

SUN.
6 P.M. 9
12
3 A.M. 6
MON.
TUES.
WED.
THUR.
FRI.
SAT.
Hunsley Th. Dyl. Chart
Upper Hand Ct.


6 P.M.
9 SUN. 3
9 MON. 3
3 A.M. 6
6 P.M. 9
12
3 A
120
110
100
90
80
70
60
50
40
30
20
10
WED.
3 A.M. 6
12
3 A.M.


6 P.M. 9 12 3 A.M. 6
9 SUN. 3
9 MON. 3
6 P.M. 9 12
3 A.M. 6
12
3 A.M. 6
9 WED. 3
6 P.M. 9 12 3 A.M. 6
9 THU. 3
120
110
100
90
80
70
60
50
40
30
20
10
Humiton Phantom Chart
5/6/76
5/13/76
89402
THE FOXBORO COMPANY
FOXBORO, MASS
U.S.A.


12
3 A.M. 6
9 MON. 3
6 P.M. 9
12
3 A.M. 6
Humiter Physitem Chart
899402
THE FOXBORO COMPANY
FOXBORO, MASS.
U.S.A.
9 WED. 3
6 P.M. 9
12
3 A.M. 6
9 THU. 3

MON.
TUE.
FRI.
SAT.
6 P.M.
9
12
3 A.M.
6
3
9
120
110
100
90
80
70
60
50
40
30
20
10
Hamilton Pharmacy Chart
Hamilton
6/27/76
859402
THE C.J. LEE CHEMICAL COMPANY
STANDARD, MASS.
U.S.A.

APPENDIX II

METHODS OF ANALYSIS

LOGAN CREEK STUDY
METHODS OF ANALYSIS
Fiscal Year, 1976

1. Fecal Coliform

Fecal Coliform colonies were isolated and enumerated by the membrane filter technique as described in Section 909C, 14th Edition, "Standard Methods for the Examination of Water and Wastewater", Page 937ff.

2. Total Suspended Sediment

Total Suspended Sediment was determined by the gravimetric procedure as described in Section 208D, 14th Edition, "Standard Methods for the Examination of Water and Wastewater", Page 94.

3. Turbidity

Turbidity was determined using a Hach 2100A turbidimeter.

4. Specific Conductivity

Specific Conductivity was determined by means of a Balsbaugh type 100 wide range conductivity bridge.

5. Laboratory pH

pH was determined with a Corning Model 110 Digital Expanded Scale pH meter with corrections for temperature and slope.

6. Water Temperature

Water temperature was determined by use of Forest Service owned thermographs and was checked at the time of each visit by means of a calibrated hand held thermometer.

7. Organic Color

Organic Color was determined by use of a Hach Model CO-1 color comparator reading platinum cobalt units from 0 to 100.

8. Flow Rate

Flows were determined using a direct reading Gurley current meter which is the property of the U.S. Forest Service. Stations were selected for uniform flow across regular sections with a minimum of debris or boulders. Lateral spacings varied from 2 feet to 6 inches depending on the size of the stream.

9. Nitrate + Nitrite

This analysis was conducted by the automated cadmium reduction method described in the "Manual of Methods for Chemical Analysis of Water and Wastes", published by the U.S. Environmental Protection Agency, Page 207ff.

10. Ortho Phosphate

Ortho phosphate was determined by the automated colorometric ascorbic acid reduction method as described in the EPA "Manual of Methods of Chemical Analysis of Water and Wastes", Page 256ff.

11. Alkalinity

Alkalinity was determined by titration to a colorometric end point with a standard acid as described in Section 403 of the 14th Edition, "Standard Methods for the Analysis of Water and Wastewater", Page 278ff.

12. Bicarbonate

Bicarbonate was determined by calculation based on the alkalinity determinations.

13. Calcium, Magnesium, Total Hardness

EDTA titrations were used to determine calcium and total hardness. Magnesium was calculated as the difference between the two. The procedure is described as method 313C in the 14th Edition of "Standards for the Analysis of Water and Wastewater", Page 223ff.

14. Sodium

Sodium concentrations were determined by the flame emission method using an atomic absorption spectrophotometer.

15. Chloride

Chloride was determined by the mercuric nitrate technique described in Section 408B, 14th Edition, "Standards for Analysis of Water and Wastewater", Page 30ff.

16. Sulfate

Sulfate concentrations were determined by the thorium titration method described in the U.S. Geological Survey manual for chemical analyses.

17. Fluoride

Fluoride concentrations were determined by the Alizarin fluorine blue method using a Technicon Auto-Analyzer.

18. Mercury

Mercury was determined by cold vapor method using an atomic absorption spectrophotometer.

19. Arsenic

Arsenic was determined using the Arsine Generation method and an atomic absorption spectrophotometer.

20. Heavy Metals

Heavy metals including iron, manganese, cadmium, lead, nickel, copper and zinc were analyzed by standard procedures using flame atomic absorption methodology.